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(54) Title: PEPTIDES AND COMPOUNDS THAT BIND TO A THROMBOPOIETIN RECEPTOR

(57) Abstract

Receptor are peptides and peptide mimetics that bind to and activate the thrombopoietin receptor. Such peptides and peptide mimetics are useful in methods for treating hematological disorders and particularly, thrombocytopenia resulting from chemotherapy, radiation therapy, or bone marrow transfusions as well as in diagnostic methods employing labeled peptides and peptide mimetics.

PEPTIDES AND COMPOUNDS THAT BIND TO A THROMBOPOIETIN RECEPTOR

CROSS-REFERENCE TO RELATED CASES

This application is a continuation-in-part of U.S. Patent Application Serial No. 08/485,301, filed June 7, 1995, and U.S. Patent Application Serial No. 08/478,128, filed June 7, 1995, each of which are herein incorporated by reference in their entirety for all purposes.

BACKGROUND OF THE INVENTION

The present invention provides peptides and compounds that bind to and activate the thrombopoietin receptor (c-mpl or TPO-R) or otherwise act as a TPO agonist. The invention has application in the fields of biochemistry and medicinal chemistry and particularly provides TPO agonists for use in the treatment of human disease.

Megakaryocytes are bone marrow-derived cells, which are responsible for producing circulating blood platelets. Although comprising <0.25% of the bone marrow cells in most species, they have >10 times the volume of typical marrow cells. See Kuter et. al. Proc. Natl. Acad. Sci. USA 91:11104-11108 (1994). Megakaryocytes undergo a process known as endomitosis whereby they replicate their nuclei but fail to undergo cell division and thereby give rise to polyploid cells. In response to a decreased platelet count, the endomitotic rate increases, higher ploidy megakaryocytes are formed, and the number of megakaryocytes may increase up to 3-fold. See Harker J. Clin. Invest. 47:458-465 (1968). In contrast, in response to an elevated platelet count, the

endomitotic rate decreases, lower ploidy megakaryocytes are formed, and the number of megakaryocytes may decrease by 50%.

The exact physiological feedback mechanism by which the mass of circulating platelets regulates the endomitotic rate and number of bone marrow megakaryocytes is not known. The circulating thrombopoietic factor involved in mediating this feedback loop is now thought to be thrombopoietin (TPO). More specifically, TPO has been shown to be the main humoral regulator in situations involving thrombocytopenia. See, e.g., Metcalf Nature 369:519-520 (1994). TPO has been shown in several studies to increase platelet counts, increase platelet size, and increase isotope incorporation into platelets of recipient animals. Specifically, TPO is thought to affect megakaryocytopoiesis in several ways: (1) it produces increases in megakaryocyte size and number; (2) it produces an increase in DNA content, in the form of polyploidy, in megakaryocytes; (3) it increases megakaryocyte endomitosis; (4) it produces increased maturation of megakaryocytes; and (5) it produces an increase in the percentage of precursor cells, in the form of small acetylcholinesterase-positive cells, in the bone marrow.

Because platelets (thrombocytes) are necessary for blood clotting and when their numbers are very low a patient is at serious risk of death from catastrophic hemorrhage, TPO has potential useful application in both the diagnosis and the treatment of various hematological disorders, for example, diseases primarily due to platelet defects. Ongoing clinical trials with TPO have indicated that TPO can be administered safely to patients. In addition, recent studies have provided a basis for the projection of efficacy of TPO therapy in the treatment of thrombocytopenia, and particularly thrombocytopenia resulting from chemotherapy, radiation therapy, or bone marrow transplantation as treatment for cancer or lymphoma. See, e.g., McDonald (1992) Am. J. Ped. Hematology/Oncology 14:8-21 (1992).

The gene encoding TPO has been cloned and characterized. See Kuter et al. Proc. Natl. Acad. Sci. USA 91:11104-11108 (1994); Barley et al. Cell 77:1117-1124

(1994); Kaushansky et al. Nature 369:568-571 (1994); Wendling et al. Nature 369:571-574 (1994); and Sauvage et al. Nature 369:533-538 (1994). Thrombopoietin is a glycoprotein with at least two forms, with apparent molecular masses of 25 kDa and 31 kDa, with a common N-terminal amino acid sequence. See, Bartley et al. Cell 77:1117-1124 (1994). Thrombopoietin appears to have two distinct regions separated by a potential Arg-Arg cleavage site. The amino-terminal region is highly conserved in man and mouse, and has some homology with erythropoietin and interferon-a and interferon-b. The carboxy-terminal region shows wide species divergence.

The DNA sequences and encoded peptide sequences for human TPO-R (also known as *c-mpl*) have been described. See Vigon et al. Proc. Natl. Acad. Sci. USA 89:5640-5644 (1992). TPO-R is a member of the haematopoietin growth factor receptor family, a family characterized by a common structural design of the extracellular domain, including four conserved C residues in the N-terminal portion and a WSXWS motif close to the transmembrane region. See Bazan Proc. Natl. Acad. Sci. USA 87:6934-6938 (1990). Evidence that this receptor plays a functional role in hematopoiesis includes observations that its expression is restricted to spleen, bone marrow, or fetal liver in mice (see Souyri et al. Cell 63:1137-1147 (1990)) and to megakaryocytes, platelets, and $CD34^+$ cells in humans (see Methia et al. Blood 82:1395-1401 (1993)). Furthermore, exposure of $CD34^+$ cells to synthetic oligonucleotides antisense to mpl RNA significantly inhibits the appearance of megakaryocyte colonies without affecting erythroid or myeloid colony formation. Some workers postulate that the receptor functions as a homodimer, similar to the situation with the receptors for G-CSF and erythropoietin.

The availability of cloned genes for TPO-R facilitates the search for agonists of this important receptor. The availability of the recombinant receptor protein allows the study of receptor-ligand interaction in a variety of random and semi-random peptide diversity generation systems. These systems include the "peptides on plasmids" system described in U.S. Patent Nos. 5,270,170 and 5,338,665;

the "peptides on phage" system described in U.S. Patent Application Serial No. 07/718,577, filed June 20, 1991, U.S. Patent Application Serial No. 07/541,108, filed June 20, 1990, and in Cwirla et al., Proc. Natl. Acad. Sci. USA 87:6378-6382 (1990); the "polysome" system described in U.S. Patent Application Serial No. 08/300,262, filed September 2, 1994, which is a continuation-in-part application based on U.S. Patent Application Serial No. 08/144,775, filed October 29, 1993 and PCT WO 95/11992; the "encoded synthetic library" system described in U.S. Patent Application Serial Nos. 08/146,886, filed November 12, 1993, 07/946,239, filed September 16, 1992, and 07/762,522, filed September 18, 1991; and the "very large scale immobilized polymer synthesis" system described in U.S. Patent No. 5,143,854; PCT Patent Publication No. 90/15070, published December 13, 1990; U.S. Patent Application Serial No. 07/624,120, filed December 6, 1990; Fodor et al. Science 251:767-773 (2/1991); Dower and Fodor Ann. Rep. Med. Chem. 26:271-180 (1991); and U.S. Patent Application Serial No. 07/805,727, filed December 6, 1991; each of the foregoing patent applications and publications is incorporated herein by reference.

The slow recovery of platelet levels in patients suffering from thrombocytopenia is a serious problem, and has lent urgency to the search for a blood growth factor agonist able to accelerate platelet regeneration. The present invention provides such an agonist.

SUMMARY OF THE INVENTION

This invention is directed, in part, to the novel and unexpected discovery that defined low molecular weight peptides and peptide mimetics have strong binding properties to the TPO-R and can activate the TPO-R. Accordingly, such peptides and peptide mimetics are useful for therapeutic purposes in treating conditions mediated by TPO (e.g., thrombocytopenia resulting from chemotherapy, radiation therapy, or bone marrow transfusions) as well as for diagnostic purposes in studying the mechanism of hematopoiesis

and for the *in vitro* expansion of megakaroycytes and committed progenitor cells.

Peptides and peptide mimetics suitable for therapeutic and/or diagnostic purposes have an IC_{50} of about 2 mM or less, as determined by the binding affinity assay set forth in Example 3 below wherein a lower IC_{50} correlates to a stronger binding affinity to TPO-R. For pharmaceutical purposes, the peptides and peptidomimetics preferably have an IC_{50} of no more than about 100 µm, more preferably, no more than 500 nM. In a preferred embodiment, the molecular weight of the peptide or peptide mimetic is from about 250 to about 8000 daltons.

When used for diagnostic purposes, the peptides and peptide mimetics preferably are labeled with a detectable label and, accordingly, the peptides and peptide mimetics without such a label serve as intermediates in the preparation of labeled peptides and peptide mimetics.

Peptides meeting the defined criteria for molecular weight and binding affinity for TPO-R comprise 9 or more amino acids wherein the amino acids are naturally occurring or synthetic (non-naturally occurring) amino acids. Peptide mimetics include peptides having one or more of the following modifications:

peptides wherein one or more of the peptidyl [-C(O)NR-] linkages (bonds) have been replaced by a non-peptidyl linkage such as a $-CH_2$-carbamate linkage [$-CH_2-OC(O)NR-$]; a phosphonate linkage; a $-CH_2$-sulfonamide [$-CH_2-S(O)_2NR-$] linkage; a urea [-NHC(O)NH-] linkage; a $-CH_2$-secondary amine linkage; or an alkylated peptidyl linkage [$-C(O)NR^6-$ where R^6 is lower alkyl];

peptides wherein the N-terminus is derivatized to a $-NRR^1$ group; to a -NRC(O)R group; to a -NRC(O)OR group; to a $-NRS(O)_2R$ group; to a -NHC(O)NHR group where R and R^1 are hydrogen or lower alkyl with the proviso that R and R^1 are not both hydrogen; to a succinimide group; to a benzyloxycarbonyl-NH- (CBZ-NH-) group; or to a benzyloxycarbonyl-NH- group having from 1 to 3 substituents on

the phenyl ring selected from the group consisting of lower alkyl, lower alkoxy, chloro, and bromo; or

peptides wherein the C terminus is derivatized to $-C(O)R^2$ where ^{2} is selected from the group consisting of lower alkoxy, and $-NR^3R^4$ where R^3 and R^4 are independently selected from the group consisting of hydrogen and lower alkyl.

Accordingly, preferred peptides and peptide mimetics comprise a compound having:

(1) a molecular weight of less than about 5000 daltons, and

(2) a binding affinity to TPO-R as expressed by an IC_{50} of no more than about 100 µm,

wherein from zero to all of the -C(O)NH- linkages of the peptide have been replaced by a linkage selected from the group consisting of a $-CH_2OC(O)NR-$ linkage; a phosphonate linkage; a $-CH_2S(O)_2NR-$ linkage; a $-CH_2NR-$ linkage; and a $-C(O)NR^6-$ linkage; and a -NHC(O)NH- linkage where R is hydrogen or lower alkyl and R^6 is lower alkyl,

further wherein the N-terminus of said peptide or peptide mimetic is selected from the group consisting of a $-NRR^1$ group; a -NRC(O)R group; a -NRC(O)OR group; a $-NRS(O)_2R$ group; a -NHC(O)NHR group; a succinimide group; a benzyloxycarbonyl-NH- group; and a benzyloxycarbonyl-NH- group having from 1 to 3 substituents on the phenyl ring selected from the group consisting of lower alkyl, lower alkoxy, chloro, and bromo, where R and R^1 are independently selected from the group consisting of hydrogen and lower alkyl,

and still further wherein the C-terminus of said peptide or peptide mimetic has the formula $-C(O)R^2$ where R^2 is selected from the group consisting of hydroxy, lower alkoxy, and $-NR^3R^4$ where R^3 and R^4 are independently selected from the group consisting of hydrogen and lower alkyl and where the nitrogen atom of the $-NR^3R^4$ group can optionally be the amine group of the N-terminus of the peptide so as to form a cyclic peptide,

and physiologically acceptable salts thereof.

In a related embodiment, the invention is directed to a labeled peptide or peptide mimetic comprising a peptide or peptide mimetic described as above having covalently attached thereto a label capable of detection.

In some embodiments of the invention, preferred peptides for use include peptides having a core structure comprising a sequence of amino acids:

$$X_1\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7$$

where X_1 is C, L, M, P, Q, V; X_2 is F, K, L, N, Q, R, S, T or V; X_3 is C, F, I, L, M, R, S, V or W; X_4 is any of the 20 genetically coded L-amino acids; X_5 is A, D, E, G, K, M, Q, R, S, T, V or Y; X_6 is C, F, G, L, M, S, V, W or Y; and X_7 is C, G, I, K, L, M, N, R or V.

In a preferred embodiment the core peptide comrpises a sequence of amino acids:

$$X_8\ G\ X_1\ X_2\ X_3\ X_4 X_5\ W\ X_7$$

where X_1 is L, M, P, Q, or V; X_2 is F, R, S, or T; X_3 is F, L, V, or W; X_4 is A, K, L, M, R, S, V, or T; X_5 is A, E, G, K, M, Q, R, S, or T; X_7 is C, I, K, L, M or V; and each X_8 residue is independently selected from any of the 20 genetically coded L-amino acids, their stereoisomeric D-amino acids; and non-natural amino acids. Preferably, each X_8 residue is independently selected from any of the 20 genetically coded L-amino acids and their stereoisomeric D-amino acids. In a preferred embodiment, X_1 is P; X_2 is T; X_3 is L; X_4 is R; X_5 is E or Q; and X_7 is I or L.

More preferably, the core peptide comprises a sequence of amino acids:

$$X_9\ X_8\ G\ X_1\ X_2\ X_3\ X_4\ X_5\ W\ X_7$$

where X_9 is A, C, E, G, I, L , M, P, R, Q, S, T, or V; and X_8 is A, C, D, E, K, L, Q, R, S, T, or V. More preferably, X_9 is A or I; and X_8 is D, E, or K.

Particularly preferred peptides include: G G C A D G P T L R E W I S F C G G; G N A D G P T L R Q W L E G R R P K N; G G C A D G P T L R E W I S F C G G K; T I K G P T L R Q W L K S R E H T S; S I E G P T L R E W L T S R T P H S; L A I E G P T L R Q W L H G N G R D T; C A D G P T L R E W I S F C; and I E G P T L R Q W L A A R A.

In further embodiments of the invention, preferred peptides for use in this invention include peptides having a core structure comprising a sequence of amino acids:

$$C\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7$$

where X_2 is K, L, N, Q, R, S, T or V; X_3 is C, F, I, L, M, R, S or V; X_4 is any of the 20 genetically coded L-amino acids; X_5 is A, D, E, G, S, V or Y; X_6 is C, F, G, L, M, S, V, W or Y; and X_7 is C, G, I, K, L, M, N, R or V. In a more preferred embodiment, X_4 is A, E, G, H, K, L, M, P, Q, R, S, T, or W. In a further embodiment, X_2 is S or T; X_3 is L or R; X_4 is R; X_5 is D, E, or G; X_6 is F, L, or W; and X_7 is I, K, L, R, or V. Particularly preferred peptides include: G G C T L R E W L H G G F C G G.

In a further embodiment, preferred peptides for use in this invention include peptides having a structure comprising a sequence of amino acids:

$$X_8\ C\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7$$

where X_2 is F, K, L, N, Q, R, S, T or V; X_3 is C, F, I, L, M, R, S, V or W; X_4 is any of the 20 genetically coded L-amino acids; X_5 is A, D, E, G, K, M, Q, R, S, T, V or Y; X_6 is C, F, G, L, M, S, V, W or Y; X_7 is C, G, I, K, L, M, N, R or V; and X_8 is any of the 20 genetically coded L-amino acids. In some embodiments, X_8 is preferably G, S, Y, or R.

The compounds described herein are useful for the prevention and treatment of diseases mediated by TPO, and particularly for treating hematological disorders, including but not limited to, thrombocytopenia resulting from chemotherapy, radiation therapy, or bone marrow transfusions. Thus, the present invention also provides a method for treating wherein a patient having a disorder that is susceptible to treatment with a TPO agonist receives, or is administered, a therapeutically effective dose or amount of a compound of the present invention.

The invention also provides for pharmaceutical compositions comprising one or more of the compounds described

herein and a physiologically acceptable carrier. These pharmaceutical compositions can be in a variety of forms including oral dosage forms, as well as inhalable powders and solutions and injectable and infusible solutions.

BRIEF DESCRIPTION OF THE FIGURES

Figures 1A-B illustrates the results of a functional assay in the presence of various peptides; the assay is described in Example 2. Figure 1A is a graphical depiction of the results of the TPO-R transfected Ba/F3 cell proliferation assay for selected peptides of the invention:

□ designating the results for G G C A D G P T L R E W I S F C G G K (biotin);

X designating the results for G G C A D G P T L R E W I S F C G G;

▲ designating the results for L A I E G P T L R Q W L H G N G R D T;

O designating the results for G N A D G P T L R Q W L E G R R P K N; and

\+ designating the results for T I K G P T L R Q W L K S R E H T S.

Figure 1B is a graphical depiction of the results with the same peptides and the parental cell line.

Figure 2A-C show the results of peptide oligomerization using the TPO-R transfected Ba/F3 cell proliferation assay. Figure 2A shows the results of the assay for the complexed biotinylated peptide (AF 12285 with streptavidin (SA)) for both the transfected and parental cell lines. Figure 2B shows the results of the assay for the free biotinylated peptide (AF 12285) for both the transfected and parental cell lines. Figure 2C shows the results of the assay for streptavidin alone for both the transfected and parental cell lines.

Figures 3A-G show the results of a series of control experiments showing the activity of TPO, the peptides of the present invention, EPO, and EPO-R binding peptides in a cell proliferation assay using either the TPO-R transfected Ba/F3

cell line and its corresponding parental line, or an EPO-dependent cell line. Figure 3A depicts the results for TPO in the cell proliferation assay using the TPO-R transfected Ba/F3 cell line and its corresponding parental line. Figure 3B depicts the results for EPO in the cell proliferation assay using the TPO-R transfected Ba/F3 cell line and its corresponding parental line. Figure 3C depicts the results for complexed biotinylated peptide (AF 12285 with streptavidin (SA)) and a complexed form of a biotinylated EPO-R binding peptide (AF 11505 with SA) in the TPO-R transfected Ba/F3 cell line. The results for the corresponding parental cell line are shown in Figure 3D. Figure 3E depicts the results for TPO in the cell proliferation assay using the EPO-dependent cell line. Figure 3F depicts the results for EPO in the cell proliferation assay using the EPO-dependent cell line. Figure 3G depicts the results for complexed biotinylated peptide (AF 12885 with streptavidin (SA)) and the complexed form of a biotinylated EPO-R binding peptide (AF 11505 with SA) in the EPO-dependent cell line.

Figures 4A-C illustrates the construction of peptides-on-plasmids libraries in vector pJS142. Figure 4A shows a restriction map and position of the genes. The library plasmid includes the *rrnB* transcriptional terminator, the *bla* gene to permit selection on ampicillin, the M13 phage intragenic region (*M13 IG*) to permit rescue of single-stranded DNA, a plasmid replication origin (*ori*), two $lacO_s$ sequences, and the *araC* gene to permit positive and negative regulation of the *araB* promoter driving expression of the *lac* fusion gene. Figure 4B shows the sequence of the cloning region at the 3' end of the *lac I* gene, including the SfiI and EagI sites used during library construction. Figure 4C shows the ligation of annealed library oligonucleotides, ON-829 and ON-830, to SfiI sites of pJS142 to produce a library. Single spaces in the sequence indicate sites of ligation.

Figures 5A-B illustrate cloning into the pELM3 and pELM15 MBP vectors. Figure 5A shows the sequence at the 3' end of the *malE* fusion gene, including the MBP coding

sequence, the poly asparagine linker, the factor Xa protease cleavagge site, and the available cloning sites. The remaining portions of the vectors are derived from pMALc2 (pELM3) and pMALp2 (pELM15), available from New England Biolabs. Figure 5B shows the sequence of the vectors after transfer of the BspEII-ScaI library fragment into AgeI-ScaI digested pELM3/pELM15. The transferred sequence includes the sequence encoding the GGG peptide linker from the pJS142 library.

Figure 6A depicts a restriction map and position of the genes for the construction of headpiece dimer libraries in vector pCMG14. The library plasmid includes: the *rrnB* transcriptional terminator, the *bla* gene to permit selection on ampicillin, the M13 phage intragenic region (*M13 IG*) to permit rescue of single-stranded DNA, a plasmid replication origin (*ori*), one $lacO_s$ ssequence, and the *araC* gene to permit positive and negative regulation of the *araB* promoter driving expression of the headpiece dimer fusion gene. Figure 6B depicts the sequence of the cloning region at the 3' end of the headpiece dimer gene, including the SfiI and EagI sites used during library construction. Figure 6C shows the ligation of annealed ON-1679, ON-829, and ON-830 to SfiI sites of pCMG14 to produce a library. Singles spaces in the sequence indicate sites of ligation.

Figures 7 to 9 show the results of further assays evaluating activity of the peptides and peptide mimETICS of the invention. In this assay mice are made thrombocytopenic with carboplatin. Figure 7 depicts typical results when Balb/C mice are treated with carboplatin (125 mg/kg intraperitoneally) on Day 0. The dashed lines represent untreated animals from three experiments. The solid line represent carboplatin-treated groups in three experiments. The heavy solid lines represent historical data. Figure 8 depicts the effect of carboplatin titration on platelet counts in mice treated with the indicated amounts of carboplatin (in mg/kg, intraperitoneally (ip) on Day 0). Figure 9 depicts amelioration of carboplatin-induced thrombocytopenia on Day 10 by peptide AF12513 (513). Carboplatin (CBP; 50-125 mg/kg,

intraperitoneally) was administered on Day 0. AF12513 (1 mg/kg, ip) was given on Days 1-9.

DESCRIPTION OF SPECIFIC EMBODIMENTS

I. DEFINITIONS AND GENERAL PARAMETERS

The following definitions are set forth to illustrate and define the meaning and scope of the various terms used to describe the invention herein.

"Agonist" refers to a biologically active ligand which binds to its complementary biologically active receptor and activates the latter either to cause a biological response in the receptor or to enhance preexisting biological activity of the receptor.

"Pharmaceutically acceptable salts" refer to the non-toxic alkali metal, alkaline earth metal, and ammonium salts commonly used in the pharmaceutical industry including the sodium, potassium, lithium, calcium, magnesium, barium, ammonium, and protamine zinc salts, which are prepared by methods well known in the art. The term also includes non-toxic acid addition salts, which are generally prepared by reacting the compounds of this invention with a suitable organic or inorganic acid. Representative salts include the hydrochloride, hydrobromide, sulfate, bisulfate, acetate, oxalate, valerate, oleate, laurate, borate, benzoate, lactate, phosphate, tosylate, citrate, maleate, fumarate, succinate, tartrate, napsylate, and the like.

"Pharmaceutically acceptable acid addition salt" refers to those salts which retain the biological effectiveness and properties of the free bases and which are not biologically or otherwise undesirable, formed with inorganic acids such as hydrochloric acid, hydrobromic acid, sulfuric acid, nitric acid, phosphoric acid and the like, and organic acids such as acetic acid, propionic acid, glycolic acid, pyruvic acid, oxalic acid, malic acid, malonic acid, succinic acid, maleic acid, fumaric acid, tartaric acid, citric acid, benzoic acid, cinnamic acid, mandelic acid,

menthanesulfonic acid, ethanesulfonic acid, p-toluenesulfonic acid, salicylic acid and the like. For a description of pharmaceutically acceptable acid addition salts as prodrugs, see Bundgaard, H., supra.

"Pharmaceutically acceptable ester" refers to those esters which retain, upon hydrolysis of the ester bond, the biological effectiveness and properties of the carboxylic acid or alcohol and are not biologically or otherwise undesirable. For a description of pharmaceutically acceptable esters as prodrugs, see Bundgaard, H., ed., Design of Prodrugs, Elsevier Science Publishers, Amsterdam (1985). These esters are typically formed from the corresponding carboxylic acid and an alcohol. Generally, ester formation can be accomplished via conventional synthetic techniques. (See, e.g., March Advanced Organic Chemistry, 3rd Ed., John Wiley & Sons, New York (1985) p. 1157 and references cited therein, and Mark et al. Encyclopedia of Chemical Technology, John Wiley & Sons, New York (1980)). The alcohol component of the ester will generally comprise (i) a C_2-C_{12} aliphatic alcohol that can or can not contain one or more double bonds and can or can not contain branched carbons or (ii) a C_7-C_{12} aromatic or heteroaromatic alcohols. This invention also contemplates the use of those compositions which are both esters as described herein and at the same time are the pharmaceutically acceptable acid addition salts thereof.

"Pharmaceutically acceptable amide" refers to those amides which retain, upon hydrolysis of the amide bond, the biological effectiveness and properties of the carboxylic acid or amine and are not biologically or otherwise undesirable. For a description of pharmaceutically acceptable amides as prodrugs, see Bundgaard, H., ed., Design of Prodrugs, Elsevier Science Publishers, Amsterdam (1985). These amides are typically formed from the corresponding carboxylic acid and an amine. Generally, amide formation can be accomplished via conventional synthetic techniques. (See, e.g., March Advanced Organic Chemistry, 3rd Ed., John Wiley & Sons, New York (1985) p. 1152 and Mark et al. Encyclopedia of Chemical Technology, John Wiley & Sons, New York (1980)). This

invention also contemplates the use of those compositions which are both amides as described herein and at the same time are the pharmaceutically acceptable acid addition salts thereof.

"Pharmaceutically or therapeutically acceptable carrier" refers to a carrier medium which does not interfere with the effectiveness of the biological activity of the active ingredients and which is not toxic to the host or patient.

"Stereoisomer" refers to a chemical compound having the same molecular weight, chemical composition, and constitution as another, but with the atoms grouped differently. That is, certain identical chemical moieties are at different orientations in space and, therefore, when pure, has the ability to rotate the plane of polarized light. However, some pure stereoisomers may have an optical rotation that is so slight that it is undetectable with present instrumentation. The compounds of the instant invention may have one or more asymmetrical carbon atoms and therefore include various stereoisomers. All stereoisomers are included within the scope of the invention.

"Therapeutically- or pharmaceutically-effective amount" as applied to the compositions of the instant invention refers to the amount of composition sufficient to induce a desired biological result. That result can be alleviation of the signs, symptoms, or causes of a disease, or any other desired alteration of a biological system. In the present invention, the result will typically involve a decrease in the immunological and/or inflammatory responses to infection or tissue injury.

Amino acid residues in peptides are abbreviated as follows: Phenylalanine is Phe or F; Leucine is Leu or L; Isoleucine is Ile or I; Methionine is Met or M; Valine is Val or V; Serine is Ser or S; Proline is Pro or P; Threonine is Thr or T; Alanine is Ala or A; Tyrosine is Tyr or Y; Histidine is His or H; Glutamine is Gln or Q; Asparagine is Asn or N; Lysine is Lys or K; Aspartic Acid is Asp or D; Glutamic Acid is Glu or E; Cysteine is Cys or C; Tryptophan is Trp or W;

Arginine is Arg or R; and Glycine is Gly or G. Additionally, Bu is Butoxy, Bzl is benzyl, CHA is cyclohexylamine, Ac is acetyl, Me is methyl, Pen is penicillamine, Aib is amino isobutyric acid, Nva is norvaline, Abu is amino butyric acid, Thi is thienylalanine, OBn is O-benzyl, and hyp is hydroxyproline.

In addition to peptides consisting only of naturally-occurring amino acids, peptidomimetics or peptide analogs are also provided. Peptide analogs are commonly used in the pharmaceutical industry as non-peptide drugs with properties analogous to those of the template peptide. These types of non-peptide compound are termed "peptide mimetics" or "peptidomimetics" (Fauchere, J. Adv. Drug Res. 15:29 (1986); Veber and Freidinger TINS p.392 (1985); and Evans et al. J. Med. Chem. 30:1229 (1987), which are incorporated herein by reference). Peptide mimetics that are structurally similar to therapeutically useful peptides may be used to produce an equivalent or enhanced therapeutic or prophylactic effect. Generally, peptidomimetics are structurally similar to a paradigm polypeptide (i.e., a polypeptide that has a biological or pharmacological activity), such as naturally-occurring receptor-binding polypeptide, but have one or more peptide linkages optionally replaced by a linkage selected from the group consisting of: $-CH_2NH-$, $-CH_2S-$, $-CH_2-CH_2-$, $-CH{=}CH-$ (*cis* and *trans*), $-COCH_2-$, $-CH(OH)CH_2-$, and $-CH_2SO-$, by methods known in the art and further described in the following references: Spatola, A.F. in Chemistry and Biochemistry of Amino Acids, Peptides, and Proteins, B. Weinstein, eds., Marcel Dekker, New York, p. 267 (1983); Spatola, A.F., Vega Data (March 1983), Vol. 1, Issue 3, Peptide Backbone Modifications (general review); Morley, Trends Pharm Sci (1980) pp. 463-468 (general review); Hudson, D. et al., Int J Pept Prot Res 14:177-185 (1979) ($-CH_2NH-$, CH_2CH_2-); Spatola et al. Life Sci 38:1243-1249 (1986) ($-CH_2-S$); Hann J. Chem. Soc Perkin Trans. I 307-314 (1982) (-CH-CH-, *cis* and *trans*); Almquist et al. J. Med. Chem. 23:1392-1398 (1980) ($-COCH_2-$); Jennings-White et al. Tetrahedron Lett 23:2533 (1982) ($-COCH_2-$); Szelke et al.

European Appln. EP 45665 CA (1982): 97:39405 (1982) ($-CH(OH)CH_2-$); Holladay et al. Tetrahedron Lett 24:4401-4404 (1983) ($-C(OH)CH_2-$); and Hruby Life Sci 31:189-199 (1982) ($-CH_2-S-$); each of which is incorporated herein by reference. A particularly preferred non-peptide linkage is $-CH_2NH-$. Such peptide mimetics may have significant advantages over polypeptide embodiments, including, for example: more economical production, greater chemical stability, enhanced pharmacological properties (half-life, absorption, potency, efficacy, etc.), altered specificity (e.g., a broad-spectrum of biological activities), reduced antigenicity, and others. Labeling of peptidomimetics usually involves covalent attachment of one or more labels, directly or through a spacer (e.g., an amide group), to non-interfering position(s) on the peptidomimetic that are predicted by quantitative structure-activity data and/or molecular modeling. Such non-interfering positions generally are positions that do not form direct contacts with the macromolecules(s) (e.g., immunoglobulin superfamily molecules) to which the peptidomimetic binds to produce the therapeutic effect. Derivitization (e.g., labeling) of peptidomimetics should not substantially interfere with the desired biological or pharmacological activity of the peptidomimetic. Generally, peptidomimetics of receptor-binding peptides bind to the receptor with high affinity and possess detectable biological activity (i.e., are agonistic or antagonistic to one or more receptor-mediated phenotypic changes).

Systematic substitution of one or more amino acids of a consensus sequence with a D-amino acid of the same type (e.g., D-lysine in place of L-lysine) may be used to generate more stable peptides. In addition, constrained peptides comprising a consensus sequence or a substantially identical consensus sequence variation may be generated by methods known in the art (Rizo and Gierasch Ann. Rev. Biochem. 61:387 (1992), incorporated herein by reference); for example, by adding internal cysteine residues capable of forming intramolecular disulfide bridges which cyclize the peptide.

Synthetic or non-naturally occuring amino acids refer to amino acids which do not naturally occur *in vivo* but which, nevertheless, can be incorporated into the peptide structures described herein. Preferred synthetic amino acids are the D-a-amino acids of naturally occurring L-a-amino acid as well as non-naturally occurring D- and L-a-amino acids represented by the formula H_2NCHR^5COOH where R^5 is 1) a lower alkyl group, 2) a cycloalkyl group of from 3 to 7 carbon atoms, 3) a heterocycle of from 3 to 7 carbon atoms and 1 to 2 heteroatoms selected from the group consisting of oxygen, sulfur, and nitrogen, 4) an aromatic residue of from 6 to 10 carbon atoms optionally having from 1 to 3 substituents on the aromatic nucleus selected from the group consisting of hydroxyl, lower alkoxy, amino, and carboxyl, 5) -alkylene-Y where alkylene is an alkylene group of from 1 to 7 carbon atoms and Y is selected from the group consisting of (a) hydroxy, (b) amino, (c) cycloalkyl and cycloalkenyl of from 3 to 7 carbon atoms, (d) aryl of from 6 to 10 carbon atoms optionally having from 1 to 3 substituents on the aromatic nucleus selected from the group consisting of hydroxyl, lower alkoxy, amino and carboxyl, (e) heterocyclic of from 3 to 7 carbon atoms and 1 to 2 heteroatoms selected from the group consisting of oxygen, sulfur, and nitrogen, (f) $-C(O)R^2$ where R^2 is selected from the group consisting of hydrogen, hydroxy, lower alkyl, lower alkoxy, and $-NR^3R^4$ where R^3 and R^4 are independently selected from the group consisting of hydrogen and lower alkyl, (g) $-S(O)_nR^6$ where n is an integer from 1 to 2 and R^6 is lower alkyl and with the proviso that R^5 does not define a side chain of a naturally occurring amino acid.

Other preferred synthetic amino acids include amino acids wherein the amino group is separated from the carboxyl group by more than one carbon atom such as b-alanine, g-aminobutyric acid, and the like.

Particularly preferred synthetic amino acids include, by way of example, the D-amino acids of naturally occurring L-amino acids, L-1-napthyl-alanine, L-2-naphthylalanine, L-cyclohexylalanine, L-2-amino isobutyric acid, the sulfoxide and sulfone derivatives of methionine

(i.e., $HOOC-(H_2NCH)CH_2CH_2-S(O)_nR^6$) where n and R_6 are as defined above as well as the lower alkoxy derivative of methionine (i.e., $HOOC-(H_2NCH)CH_2CH_2-OR^6$ where R^6 is as defined above).

"Detectable label" refers to materials, which when covalently attached to the peptides and peptide mimetics of this invention, permit detection of the peptide and peptide mimetics *in vivo* in the patient to whom the peptide or peptide mimetic has been administered. Suitable detectable labels are well known in the art and include, by way of example, radioisotopes, fluorescent labels (e.g., fluorescein), and the like. The particular detectable label employed is not critical and is selected relative to the amount of label to be employed as well as the toxicity of the label at the amount of label employed. Selection of the label relative to such factors is well within the skill of the art.

Covalent attachment of the detectable label to the peptide or peptide mimetic is accomplished by conventional methods well known in the art. For example, when the ^{125}I radioisotope is employed as the detectable label, covalent attachment of ^{125}I to the peptide or the peptide mimetic can be achieved by incorporating the amino acid tyrosine into the peptide or peptide mimetic and then iodating the peptide. If tyrosine is not present in the peptide or peptide mimetic, incorporation of tyrosine to the N or C terminus of the peptide or peptide mimetic can be achieved by well known chemistry. Likewise, ^{32}P can be incorporated onto the peptide or peptide mimetic as a phosphate moiety through, for example, a hydroxyl group on the peptide or peptide mimetic using conventional chemistry.

II. OVERVIEW

The present invention provides compounds that bind to and activate the TPO-R or otherwise behave as a TPO agonist. These compounds include "lead" peptide compounds and "derivative" compounds constructed so as to have the same or similar molecular structure or shape as the lead compounds but

that differ from the lead compounds either with respect to susceptibility to hydrolysis or proteolysis and/or with respect to other biological properties, such as increased affinity for the receptor. The present invention also provides compositions comprising an effective amount of a TPO agonist, and more particularly a compound, that is useful for treating hematological disorders, and particularly, thrombocytopenia associated with chemotherapy, radiation therapy, or bone marrow transfusions.

III. IDENTIFICATION OF TPO-AGONISTS

Peptides having a binding affinity to TPO-R can be readily identified by random peptide diversity generating systems coupled with an affinity enrichment process.

Specifically, random peptide diversity generating systems include the "peptides on plasmids" system described in U.S. Patent Nos. 5,270,170 and 5,338,665; the "peptides on phage" system described in U.S. Patent Application Serial No. 07/718,577, filed June 20, 1991 which is a continuation in part application of U.S. Patent Application Serial No. 07/541,108, filed June 20, 1990, and in Cwirla et al., Proc. Natl. Acad. Sci. USA 87:6378-6382 (1980); the "polysome system" described in U.S. Patent Application Serial No. 08/300,262, filed September 2, 1994, which is a continuation-in-part application based on U.S. Patent Application Serial No. 08/144,775, filed October 29, 1993 and PCT WO 95/11992; the "encoded synthetic library (ESL)" system described in U.S. Patent Application Serial No. 08/146,886, filed November 12, 1993 which is a continuation in part application of U.S. Patent Application Serial No. 07/946,239, filed September 16, 1992, which is a continuation in part application of U.S. Patent Application Serial No. 07/762,522, filed September 18, 1991; and the "very large scale immobilized polymer synthesis" system described in U.S. Patent No. 5,143,854; PCT Patent Publication No. 90/15070, published December 13, 1990; U.S. Patent Application Serial No. 07/624,120, filed December 6, 1990; Fodor et al. Science

251:767-773 (2/1991); Dower and Fodor Ann. Rep. Med. Chem. 26:271-180 (1991); and U.S. Patent Application Serial No. 805,727, filed December 6, 1991.

Using the procedures described above, random peptides were generally designed to have a defined number of amino acid residues in length (e.g., 12). To generate the collection of oligonucleotides encoding the random peptides, the codon motif (NNK)x, where N is nucleotide A, C, G, or T (equimolar; depending on the methodology employed, other nucleotides can be employed), K is G or T (equimolar), and x is an integer corresponding to the number of amino acids in the peptide (e.g., 12) was used to specify any one of the 32 possible codons resulting from the NNK motif: 1 for each of 12 amino acids, 2 for each of 5 amino acids, 3 for each of 3 amino acids, and only one of the three stop codons. Thus, the NNK motif encodes all of the amino acids, encodes only one stop codon, and reduces codon bias.

In the systems employed, the random peptides were presented either on the surface of a phage particle, as part of a fusion protein comprising either the pIII or the pVIII coat protein of a phage fd derivative (peptides on phage) or as a fusion protein with the LacI peptide fusion protein bound to a plasmid (peptides on plasmids).

The phage or plasmids, including the DNA encoding the peptides, were identified and isolated by an affinity enrichment process using immobilized TPO-R. The affinity enrichment process, sometimes called "panning," involves multiple rounds of incubating the phage, plasmids, or polysomes with the immobilized receptor, collecting the phage, plasmids, or polysomes that bind to the receptor (along with the accompanying DNA or mRNA), and producing more of the phage or plasmids (along with the accompanying LacI-peptide fusion protein) collected. The extracellular domain (ECD) of the TPO-R typically was used during panning.

After several rounds of affinity enrichment, the phage or plasmids and accompanying peptides were examined by ELISA to determine if the peptides bind specifically to TPO-R. This assay was carried out similarly to the procedures used in

the affinity enrichment process, except that after removing unbound phage, the wells were typically treated with rabbit anti-phage antibody, then with alkaline phosphatase (AP)-conjugated goat anti-rabbit antibody. The amount of alkaline phosphatase in each well was determined by standard methods. A similar ELISA procedure for use in the pepides on plasmids system is described in detail below.

By comparing test wells with control wells (no receptor), one can determine whether the fusion proteins bind to the receptor specifically. The phage pools found to bind to TPO-R were screened in a colony lift probing format using radiolabelled monovalent receptor. This probe can be produced using protein kinase A to phosphorylate a kemptide sequence fused to the C-terminus of the soluble receptor. The "engineered" form of the TPO receptor is then expressed in host cells, typically CHO cells. Following PI-PLC harvest of the receptors, the receptor was tested for binding to TPO or TPO-R specific phage clones. The receptor is then labeled to high specific activity with ^{33}P for use as a monovalent probe to identify high affinity ligands using colony lifts.

Peptides found to bind specifically to the receptor were then synthesized as the free peptide (e.g., no phage) and tested in a blocking assay. The blocking assay was carried out in similar fashion to the ELISA , except that TPO or a reference peptide was added to the wells before the fusion protein (the control wells were of two types: (1) no receptor; and (2) no TPO or reference peptide). Fusion proteins for which the binding to the receptor was blocked by TPO or the reference peptide contain peptides in the random peptide portion that are preferred compounds of the invention.

TPO-R, as well as its extracellular domain, were produced in recombinant host cells. One useful form of TPO-R is constructed by expressing the protein as a soluble protein in baculovirus transformed host cells using standard methods; another useful form is constructed with a signal peptide for protein secretion and for glycophospholipid membrane anchor attachment. This form of anchor attachment is called

"PIG-tailing". See Caras and Wendell Science 243:1196-1198 (1989) and Lin et al. Science 249:677-679 (1990).

Using the PIG-tailing system, one can cleave the receptor from the surface of the cells expressing the receptor (e.g., transformed CHO cells selected for high level expression of receptor with a cell sorter) with phospholipase C. The cleaved receptor still comprises a carboxy terminal sequence of amino acids, called the "HPAP tail", from the signal protein for membrane attachment and can be immobilized without further purification. The recombinant receptor protein can be immobilized by coating the wells of microtiter plates with an anti-HPAP tail antibody (Ab 179 or MAb 179), blocking non-specific binding with bovine serum albumin (BSA) in PBS, and then binding cleaved recombinant receptor to the antibody. Using this procedure, one should perform the immobilization reaction in varying concentrations of receptor to determine the optimum amount for a given preparation, because different preparations of recombinant protein often contain different amounts of the desired protein. In addition, one should ensure that the immobilizing antibody is completely blocked (with TPO or some other blocking compound) during the affinity enrichment process. Otherwise, unblocked antibody can bind undesired phage during the affinity enrichment procedure. One can use peptides that bind to the immobilizing antibody to block unbound sites that remain after receptor immobilization to avoid this problem or one can simply immobilize the receptor directly to the wells of microtiter plates, without the aid of an immobilizing antibody. See U.S. Patent Application Serial No. 07/947,339, filed September 18, 1992, incorporated herein by reference.

When using random peptide generation systems that allow for multivalent ligand-receptor interaction, one must recognize that the density of the immobilized receptor is an important factor in determining the affinity of the ligands that can bind to the immobilized receptor. At higher receptor densities (e.g., each anti-receptor antibody-coated well treated with 0.25 to 0.5 mg of receptor), multivalent binding is more likely to occur than at lower receptor densities

(e.g., each anti-receptor antibody-coated well treated with 0.5 to 1 ng of the receptor). If multivalent binding is occurring, then one will be more likely to isolate ligands with relatively lower affinity, unless one uses high densities of immobilized receptor to identify lead compounds and uses lower receptor densities to isolate higher affinity derivative compounds.

To discriminate among higher affinity peptides, a monovalent receptor probe frequently is used. This probe can be produced using protein kinase A to phosphorylate a kemptide sequence fused to the C-terminus of the soluble receptor. The "engineered" form of the TPO receptor is then expressed in host cells, typically CHO cells. Following PI-PLC harvest of the receptors, the receptor was tested for binding to TPO or TPO-R specific phage clones. The receptor is then labeled to high specific activity with ^{33}P for use as a monovalent probe to identify high affinity ligands using colony lifts.

Preferred screening methods to facilitate identification of peptides which bind TPO-R involve first identifying lead peptides which bind to the extracellular domain of the receptor and then making other peptides which resemble the lead peptides. Specifically, using a pIII or pVIII-based peptides on phage system, a random library can be screened to discover a phage that presents a peptide that binds to TPO-R. The phage DNAs are sequenced to determine the sequences of the peptides displayed on the surface of the phages.

Clones capable of specific binding to the TPO-R were identified from a random linear 10-mer pVIII library and a random cyclic 10-mer and 12-mer pVIII libraries. The sequences of these peptides serve as the basis for the construction of other peptide libraries designed to contain a high frequency of derivatives of the initially identified peptides. These libraries can be synthesized so as to favor the production of peptides that differ from the binding peptide in only a few residues. This approach involves the synthesis of an oligonucleotide with the binding peptide coding sequence, except that rather than using pure

preparations of each of the four nucleoside triphosphates in the synthesis, one uses mixtures of the four nucleoside triphosphates (i.e., 55% of the "correct" nucleotide, and 15% each of the other three nucleotides is one preferred mixture for this purpose and 70% of the "correct" nucleotide and 10% of each of the other three nucleotides is another preferred mixture for this purpose) so as to generate derivatives of the binding peptide coding sequence.

A variety of strategies were used to derivatize the lead peptides by making "mutagenesis on a theme" libraries,. These included a pVIII phagemid mutagenesis library based on the consensus sequence mutagenized at 70:10:10:10 frequency and extended on each terminus with random residues to produce clones which enclode the sequence XXXX (C, S, P, or R) TLREWL XXXXXX (C or S). A similar extended/mutagenized library was constructed using the peptides-on-plasmids system to produce clones which enclode the sequence XXXXX (C, S, P, or R) TLREWL XXXXXXX. An additional extended/mutagenized library, XXXX (C, S, P, or R) TLREWL XXXXXX (C or S), was constructed using the polysome display system. All three libraries were screened with peptide elution and probed with radiolabeled monovalent receptor.

The "peptides on plasmids" techniques was also used for peptide screening and mutagenesis studies and is described in greater detail in U.S. Patent no. 5,338,665, which is incorporated herein by reference for all purposes. According to this approach, random peptides are fused at the C-terminus of LacI through expression from a plasmid vector carrying the fusion gene. Linkage of the LacI-peptide fusion to its encoding DNA occurs via the *lacO* sequences on the plasmid, forming a stable peptide-LacI-plasmid complex that can be screened by affinity purification (panning) on an immobilized receptor. The plasmids thus isolated can then be reintroduced into *E. coli* by electroporation to amplify the selected population for additional rounds of screening, or for the examination of individual clones.

In addition, random peptide screening and mutagenesis studies were performed using a modified C-terminal

Lac-I display system in which display valency was reduced ("headpiece dimer" display system). The libraries were screened and the resulting DNA inserts were cloned as a pool into a maltose binding protein (MBP) vector allowing their expression as a C-terminal fusion protein. Crude cell lysates from randomly picked individual MBP fusion clones were then assayed for TPO-R binding in an ELISA format, as discussed above.

Peptide mutagenesis studies were also conducted using the polysome display system, as described in co-pending application U.S. Patent Application Serial No. 08/300,262, filed September 2, 1994, which is a continuation-in-part application based on U.S. Patent Application Serial No. 08/144,775, filed October 29, 1993 and PCT WO 95/11992, each of which is incorporated herein by references for all purposes. A mutagenesis library was constructed based on the sequence X X X X (C,P,R,or S) t l r e f l X X X X X X (C or S), in which X represents a random NNK codon, and the lower case letters represent amino acid codons containing 70:10:10:10 mutagenesis at positions 1 and 2 and K (G or T) at position 3 of the codon. The library was panned for 5 rounds against TPO receptor which had been immobilzed on magnetic beads. After the fifth round, the PCR amplified pool was cloned into pAFF6 and the ELISA positive clones were sequenced. The sequences were subcloned into an MBP vector and their binding affinities were determined by an MBP ELISA.

To imobilize the TPO-R for polysome screening, Ab 179 was first chemically conjugated to tosyl-activated magnetic beads (available from Dynal Corporation) as described by the manufacturer. The beads were incubated with antibody in 0.5 M borate buffer (pH 9.5) overnight at room temperature. The beads were washed and combined with TPO-R containing the "HPAP" tail. The antibody coated beads and receptor were incubated for 1 hour at 4°C, and the beads were washed again prior to adding the polysome library.

Screening of the various libraries described above yielded the TPO receptor binding peptides shown in Tables 1 and 2 below, as well as others not listed herein.

TABLE 1

Peptide
R E G P T L R Q W M
R E G P T L R Q W M
S R G M T L R E W L
E G P T L R G W L A
R E G Q T L K E W L
E R G P F W A K A C
R E G P R C V M W M
C S G L T L R E W L V C
C L T G P F V T Q W L Y E C
C G E G L T L T Q W L E H C
C R A G P T L L E W L T L C
C R A G P T L L E W L T L C
C R Q G P T L T A W L L E C
C A D G P T L R E W I S F C
C E L V G P S L M S W L T C
C G T E G P T L S T W L D C
C D Q L G V T L S R W L E C
S G T G L T L R E W L G S F S L L S
C P E G P T L L Q W L K R G Y S S C
R G D G P T L S Q W L Y S L M I M C
M V A G P T L R E F I A S L P I H C
S M Q G P T F R E W V S M M K V L C
S V Q C G P T L R Q W L A A R N H L S
G N A D G P T L R Q W L E G R R P K N
S V R C G P T L R Q W L A A R T H L S
L A I E G P T L R Q W L H G N G R D T
H G R V G P T L R E W K T Q V A T K K
C A D G P T L R E W I S F C
I S D G P T L K E W L S V T R G A S

S I E G P T L R E W L T S R T P H S
T I K G P T L R Q W L K S R E H T S
G N A D G P T L R Q W L E G R R P K N
S I E G P T L R E W L T S R T P H S
I S D G P T L K E W L S V T R G A S

TABLE 2

Peptide
C S L E D L R K R C
C R R S E L L E R C
C T F K Q F L D G C
C T R G E W L R C C
C T L R Q W L Q G C
C T L E E L R A C C
C T R E E L M R L C
C Q R A D L I N F C
C N R N D L L L F C
C T R T E W L H G C
C T L E F M N G C
C S L G E L R R L C
C N I N Q L R S I C
C T M R Q F L V C C
C T R S E W L E R C
C T L H E Y L S G C
C T R E E L L R Q C
C T F R E F V N G C
C S R A D F L A A C
C S C A Q V V Q C C
C T L R Q W I L L G M C

C T L R E W L H G G F C
C T L R A W L M S E T C
C T L R A W L M E S C C
C T F Q V W K L A R N C
C L L R E W L D X R T C
C V L R E W L L X X S C
C L L S E F L A G Q Q C
C S L R Q Y L D F G L G S C
C T L Q E L K Q S S L Y E C
C D L S E L K T H G Y A Y C
C K L S D W L M N G V A A C
C S L Q E F L S H G G Y V C
C S L K E F L H S G L M Q C
C T F R Q L L E Y G V S S C
C T M R E F L V A S G V A C
C T L A E F L A S G V E Q C
C T L A E F L A S G V E Q C
C T L K E W L V S H E V W C
C T L R E F L S L G M N A C
C T L R E F L D P T T A V C
C S L L E F L A L G V A L C
G G G R G C T L K Q W K Q G D C G R S
C N R S Q L L A A C
C T L Q Q W L S G C
C T L R E F K A G C
C T R A Q F L K G C
C T L R E F N R G C
C T L S D F K R G C
C T F R Q W K E A C
C T L S E F R G G C
C T L Q E F L E G C
C T L Q Q W K D G C

C T R S Q W L E G C	
C S L Q E F K H G C	
C T L G E W K R G C	
C T L W G C G K R G C	
C T L Q E W R G G C	
C T R L S G C W L C	
C T R T Q W L L D C	
C T L A E F R R G C	
C T S T Q W L L A C	
C S R S Q F L R S C	
C T L R E W L E G C	
C T L R E F L L M G A C	
C T L K E W L L W S S C	
C T L L E W L R N P V C	
C T L R Q W L G D A W C	
C T L G Q W L Q M G M C	
C T L R E W V F A G L C	
C L L L E F L S G A D C	
C T L G E F L A G H L C	
C R L R E F L V D L T C	
C S F R S W L V D Q T C	
C T L R E W L E D L G C	
C T L Q D W L V S W T C	
C T L S E W L S E L S C	
C T L M Q W L G G W P C	
C T L R E W L S Y G T C	
C T L Q E W L S G G L C	
G S H G C T L R E W L C M K I V P C	
Q W Q G C T L R D C I L R G V F W S	
S V N S C T L R E F L T G C R V F C	
S Y D G C T L R H W L M D I Y G D C	
Q R S G C T L R D W V L L N C L A S	

N Y R G C T L S Q W V S E Q I V G C	
G R S G C T L R E Y L G G M C Y L S	
A S W Y C T V P E L M E M Q L P E C	
G S T G C T L R E X L H M L G L D C	
A C E G C T L R Q W L E Y V R V G C	
A Q R G C T L Q Y F V S Y G X D M C	
G V C G C T L R E F L A I P H T S C	
S E G G C T L R E W V A S S L A N C	
S N S R C T L R E W I I Q G C D F S	
S N S R C T L R E W I I Q G C D F S	
C L G C T L S Q W R K R T R C D T H	
Y R G C S R A Q L L G G E C R K K	
G R G C T L K Q W K Q G D C G R S	
V R G G C A L R D W V A G E C F D W T	
L W R G C T L N G F K S R H C G S P E	
C T L R S W K H R G C A P	
G R G C T R A Q W L A G C C T G H	
R A G C T L R E F R K G C L A L	
K R G C T L A E M I R G C N R S N	
G R G C T L K Q W K Q G D C G R S	
R W R G C S L A K L K K G A A C G R G	
R G G C T L R E W R R V R V I N	
G R G C T L K Q W K Q G D C G R S	
R Y G C T R H Q W L V G T C V R H	

IC_{50} values for some additional representative peptides are given in the table below. A variety of methods can be used to evaluate IC_{50} values. For example, an equilibrium binding ELISA assay, using either MBP-TPO or lacI-peptide tracer, was used to determine whether the peptides inhibit the binding of TPO to the extracellular domain of the TPO receptor. Typically, the IC_{50} value were

determined using the free peptide. The IC_{50} value can be determined using the free peptide, which optionally can be C-terminally amidated, or can be prepared as an ester or other carboxy amide.

To recreate the exact sequence displayed on the phage, the N-terminal and C-terminal amino acids of the synthetic peptides are often preceded by one or two glycine residues. These glycines are not believed to be necessary for binding or activity. Likewise, to mimic the exact sequence of peptides displayed on polysomes, the C-terminal amino acids of the synthetic peptides are often preceded by the sequence M A S. Again, this sequence is not believed to be necessary for binding or activity.

IC_{50} values are indicated symbolically by the symbols "-", "+", and "++". For examples, those peptides which showed IC_{50} values in excess of 200 μM are indicated with a "-". Those peptides which gave IC_{50} values of less than or equal to 200 μM are given a "+", while those which gave IC_{50} values of 500 nm or less are indicated with a "++". Those peptides which gave IC_{50} values at or near the cutoff point for a particular symbol are indicated with a hybrid designator, e.g., "+/-". Those peptides for which IC_{50} values were not determined are listed as "N.D.". The IC_{50} value for peptides having the structure: G G C T L R E W L H G G F C G G was 500 nm or less. (Note the N-terminal and C-terminal amino acids were preceded by two glycines to recreate the exact sequence displayed by the phage. These glycines are not believed to be necessary for binding or activity.)

TABLE 3

Peptide	Affinity
G G C A D G P T L R E W I S F C G G	++
G N A D G P T L R Q W L E G R R P K N	++
G G C A D G P T L R E W I S F C G G K	++
T I K G P T L R Q W L K S R E H T S	++
G P T L R Q W L	-

L A I E G P T L R Q W L H G N G R D T	++
S I E G P T L R E W L T S R T P H S	++

The tables above, especially Table 3, illustrate that a preferred core peptide comprises a sequence of amino acids:

$$X_1\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7$$

where X_1 is C, L, M, P, Q, V; X_2 is F, K, L, N, Q, R, S, T or V; X_3 is C, F, I, L, M, R, S, V or W; X_4 is any of the 20 genetically coded L-amino acids; X_5 is A, D, E, G, K, M, Q, R, S, T, V or Y; X_6 is C, F, G, L, M, S, V, W or Y; and X_7 is C, G, I, K, L, M, N, R or V.

In a preferred embodiment the core peptide comprises a sequence of amino acids:

$$X_8\ G\ X_1\ X_2\ X_3\ X_4 X_5\ W\ X_7$$

where X_1 is L, M, P, Q, or V; X_2 is F, R, S, or T; X_3 is F, L, V, or W; X_4 is A, K, L, M, R, S, V, or T; X_5 is A, E, G, K, M, Q, R, S, or T; X_7 is C, I, K, L, M or V; and each X_8 residue is independently selected from any of the 20 genetically coded L-amino acids, their stereoisomeric D-amino acids; and non-natural amino acids. Preferably, each X_8 residue is independently selected from any of the 20 genetically coded L-amino acids and their stereoisomeric D-amino acids. In a preferred embodiment, X_1 is P; X_2 is T; X_3 is L; X_4 is R; X_5 is E or Q; and X_7 is I or L.

More preferably, the core peptide comprises a sequence of amino acids:

$$X_9\ X_8\ G\ X_1\ X_2\ X_3\ X_4\ X_5\ W\ X_7$$

where X_9 is A, C, E, G, I, L, M, P, R, Q, S, T, or V; and X_8 is A, C, D, E, K, L, Q, R, S, T, or V. More preferably, X_9 is A or I; and X_8 is D, E, or K.

Particularly preferred peptides include: G G C A D G P T L R E W I S F C G G; G N A D G P T L R Q W L E G R R P K N; G G C A D G P T L R E W I S F C G G K; T I K G P T L R Q W L K S R E H T S; S I E G P T L R E W L T S R T P H S; L A I E G P T L R Q W L H G N G R D T; C A D G P T L R E W I S F C; and I E G P T L R Q W L A A R A.

In further embodiments of the invention, preferred peptides for use in this invention include peptides having a core structure comprising sequence of amino acids: sequence of amino acids:

$$C\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7$$

where X_2 is K, L, N, Q, R, S, T or V; X_3 is C, F, I, L, M, R, S or V; X_4 is any of the 20 genetically coded L-amino acids; X_5 is A, D, E, G, S, V or Y; X_6 is C, F, G, L, M, S, V, W or Y; and X_7 is C, G, I, K, L, M, N, R or V. In a more preferred embodiment, X_4 is A, E, G, H, K, L, M, P, Q, R, S, T, or W. In a further embodiment, X_2 is S or T; X_3 is L or R; X_4 is R; X_5 is D, E, or G; X_6 is F, L, or W; and X_7 is I, K, L, R, or V. Particularly preferred peptides include: G G C T L R E W L H G G F C G G.

In a further embodiment, preferred peptides for use in this invention include peptides having a structure comprising a sequence of amino acids:

$$X_8\ C\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7$$

where X_2 is F, K, L, N, Q, R, S, T or V; X_3 is C, F, I, L, M, R, S, V or W; X_4 is any of the 20 genetically coded L-amino acids; X_5 is A, D, E, G, K, M, Q, R, S, T, V or Y; X_6 is C, F, G, L, M, S, V, W or Y; X_7 is C, G, I, K, L, M, N, R or V; and X_8 is any of the 20 genetically coded L-amino acids. In some embodiments, X_8 is preferably G, S, Y, or R.

Peptides and peptidomimetics having an IC_{50} of greater than about 100 mM lack sufficient binding to permit use in either the diagnostic or therapeutic aspects of this invention. Preferably, for diagnostic purposes, the peptides and peptidomimetics have an IC_{50} of about 2 mM or less and, for pharmaceutical purposes, the peptides and peptidomimetics have an IC_{50} of about 100 μM or less.

The binding peptide sequence also provides a means to determine the minimum size of a TPOR binding compound of the invention. Using the "encoded synthetic library" (ESL) system or the "very large scale immobilized polymer synthesis" system, one can not only determine the minimum size of a peptide with such activity, but one can also make all of the

peptides that form the group of peptides that differ from the preferred motif (or the minimum size of that motif) in one, two, or more residues. This collection of peptides can then be screened for ability to bind to TPO-receptor. These immobilized polymers synthesis systems or other peptide synthesis methods can also be used to synthesize truncation analogs, deletion analogs, substitution analogs, and combinations thereof all of the peptide compounds of the invention.

The peptides and peptide mimetics of the present invention were also evaluated in a thrombopoietin dependent cell proliferation assay, as described in greater detail in Example 2 below. Cell proliferation is measured by techniques known in the art, such as an MTT assay which correlates with ^{3}H-thymidine incorporation as an indication of cell proliferation (see Mossmann <u>J. Immunol. Methods</u> 65:55 (1983)). The peptides tested stimulated proliferation of TPO-R transfected Ba/F3 cells in a dose dependent manner as shown in Figure 1A. These peptides have no effect on the parental cell line as shown in Figure 1B.

Figures 7 to 9 show the results of a further assay evaluating activity of the peptides and peptide mimetics of the invention. In this assay mice are made thrombocytopenic with carboplatin. Figure 7 depicts typical results when Balb/C mice are treated with carboplatin (125 mg/kg intraperitoneally) on Day 0. The dashed lines represent untreated animals from three experiments. The solid line represent carboplatin-treated groups in three experiments. The heavy solid lines represent historical data. Figure 8 depicts the effect of carboplatin titration on platelet counts in mice treated with the indicated amounts of carboplatin (in mg/kg, intraperitoneally (ip) on Day 0). Figure 9 depicts amelioration of carboplatin-induced thrombocytopenia on Day 10 by peptide AF12513 (513). Carboplatin (CBP; 50-125 mg/kg, intraperitoneally) was administered on Day 0. AF12513 (1 mg/kg, ip) was given on Days 1-9. These results show the peptides of the invention can ameliorate thrombocytopenia in a mouse model.

In addition, certain peptides of the present invention can be dimerized or oligomerized, thereby increasing the affinity and/or activity of the compounds. To investigate the effect that peptide dimerization/oligomerization has on TPO mimetic potency in cell proliferation assays, a C-terminally biotinylated analog of the peptide G G C A D G P T L R E W I S F C G G was synthesized (G G C A D G P T L R E W I S F C G G K (Biotin)). The peptide was preincubated with streptavidin in serum-free HEPES-buffered RPMI at a 4:1 molar ratio. The complex was tested for stimulation of cell proliferation of TPO-R transfected Ba/F3 cells, as above, alongside free biotinylated peptide and the unbiotinylated parental peptide. Figure 2A shows the results of the assay for the complexed biotinylated peptide (AF 12885 with streptavidin (SA)) for both the transfected and parental cell lines. Figure 2B shows the results of the assay for the free biotinylated peptide (AF 12285) for both the transfected and parental cell lines. Figure 2C shows the results of the assay for streptavidin alone for both the transfected and parental cell lines. These figures illustrate that the pre-formed complex was approximately 10 times as potent as the free peptide.

The specificity of the binding and activity of the peptides of the invention was also examined by studying the cross reactivity of the peptides for the erythropoieitin receptor (EPO-R). The EPO-R is also a member of the haematopoietin growth factor receptor family, as is TPO-R. The peptides of the invention, as well as TPO, EPO, and a known EPO-binding peptide, were examined in a cell proliferation assay using an EPO-dependent cell line. This assay utilized FDCP-1, a growth factor dependent murine multi-potential primitive haematopoietic progenitor cell line (see, e.g., Dexter et al. J. Exp. Med. 152:1036-1047 (1981)) as the parental cell line. This cell line can proliferate, but not differentiate when supplemented with WEHI-3-conditioned media (a medium that contains IL-3, ATCC number T1B68). The parental cell line is transfected with human or murine EPO-R to produce the FDCP-1-EPO-R cell line.

These transfected cell lines can proliferate, but not differentiate in the presence of human or murine EPO.

The cells were grown to half stationary density in the presence of the necessary growth factors. The cells are then washed in PBS and starved for 16-24 hours in whole media without the growth factors. After determining the viability of the cells, stock solutions (in whole media without the growth factors) are made to give about 10^5 cells per 50 microliters. Serial dilutions of the compounds (typically, the free solution phase peptide as opposed to a phage-bound or other bound or immobilized peptide) to be tested are made in 96-well tissue culture plates for a final volume of 50 microliters per well. Cells (50 microliters) are added to each well and the cells are incubated for 24-48 hours, at which point the negative controls should die or be quiescent. Cell proliferation is then measured by techniques known in the art, such as an MTT assay.

Figures 3A-G show the results of a series of control experiments showing the activity of TPO, the peptides of the present invention, EPO, and EPO-R binding peptides in a cell proliferation assay using either the TPO-R transfected Ba/F3 cell line and its corresponding parental line, or an EPO-dependent cell line and its corresponding parental line. Figure 3A depicts the results for TPO in the cell proliferation assay using the TPO-R transfected Ba/F3 cell line and its corresponding parental line. Figure 3B depicts the results for EPO in the cell proliferation assay using the TPO-R transfected Ba/F3 cell line and its corresponding parental line. Figure 3C depicts the results for complexed biotinylated peptide (AF 12285 with streptavidin (SA)) and a complexed form of a biotinylated EPO-R binding peptide (AF 11505 with SA) in the TPO-R transfected Ba/F3 cell line. The results for the corresponding parental cell line are shown in Figure 3D. Figure 3E depicts the results for TPO in the cell proliferation assay using the EPO-dependent cell line. Figure 3F depicts the results for EPO in the cell proliferation assay using the EPO-dependent cell line. Figure 3G depicts the results for complexed biotinylated peptide (AF 12285 with

streptavidin (SA)) and the complexed form of a biotinylated EPO-R binding peptide (AF 11505 with SA) in the EPO-dependent cell line. These results show that the peptides of the invention bind and activate the TPO-R with a high degree of specificity.

IV. PREPARATION OF PEPTIDES AND PEPTIDE MIMETICS

A. SOLID PHASE SYNTHESIS

The peptides of the invention can be prepared by classical methods known in the art, for example, by using standard solid phase techniques. The standard methods include exclusive solid phase synthesis, partial solid phase synthesis methods, fragment condensation, classical solution synthesis, and even by recombinant DNA technology. See, e.g., Merrifield J. Am. Chem. Soc. 85:2149 (1963), incorporated herein by reference. On solid phase, the synthesis is typically commenced from the C-terminal end of the peptide using an alpha-amino protected resin. A suitable starting material can be prepared, for instance, by attaching the required alpha-amino acid to a chloromethylated resin, a hydroxymethyl resin, or a benzhydrylamine resin. One such chloromethylated resin is sold under the tradename BIO-BEADS SX-1 by Bio Rad Laboratories, Richmond, CA, and the preparation of the hydroxymethyl resin is described by Bodonszky et al. Chem. Ind. (London) 38:1597 (1966). The benzhydrylamine (BHA) resin has been described by Pietta and Marshall Chem. Commn. 650 (1970) and is commercially available from Beckman Instruments, Inc., Palo Alto, CA, in the hydrochloride form.

Thus, the compounds of the invention can be prepared by coupling an alpha-amino protected amino acid to the chloromethylated resin with the aid of, for example, cesium bicarbonate catalyst, according to the method described by Gisin Helv. Chim. Acta. 56:1467 (1973). After the initial coupling, the alpha-amino protecting group is removed by a choice of reagents including trifluoroacetic acid (TFA) or hydrochloric acid (HCl) solutions in organic solvents at room temperature.

The alpha-amino protecting groups are those known to be useful in the art of stepwise synthesis of peptides. Included are acyl type protecting groups (e.g. formyl, trifluoroacetyl, acetyl), aromatic urethane type protecting groups (e.g. benzyloxycarboyl (Cbz) and substituted Cbz), aliphatic urethane protecting groups (e.g. t-butyloxycarbonyl (Boc), isopropyloxycarbonyl, cyclohexyloxycarbonyl) and alkyl type protecting groups (e.g. benzyl, triphenylmethyl). Boc and Fmoc are preferred protecting groups. The side chain protecting group remains intact during coupling and is not split off during the deprotection of the amino-terminus protecting group or during coupling. The side chain protecting group must be removable upon the completion of the synthesis of the final peptide and under reaction conditions that will not alter the target peptide.

The side chain protecting groups for Tyr include tetrahydropyranyl, tert-butyl, trityl, benzyl, Cbz, Z-Br-Cbz, and 2,5-dichlorobenzyl. The side chain protecting groups for Asp include benzyl, 2,6-dichlorobenzyl, methyl, ethyl, and cyclohexyl. The side chain protecting groups for Thr and Ser include acetyl, benzoyl, trityl, tetrahydropyranyl, benzyl, 2,6-dichlorobenzyl, and Cbz. The side chain protecting group for Thr and Ser is benzyl. The side chain protecting groups for Arg include nitro, Tosyl (Tos), Cbz, adamantyloxycarbonyl mesitoylsulfonyl (Mts), or Boc. The side chain protecting groups for Lys include Cbz, 2-chlorobenzyloxycarbonyl (2-Cl-Cbz), 2-bromobenzyloxycarbonyl (2-BrCbz), Tos, or Boc.

After removal of the alpha-amino protecting group, the remaining protected amino acids are coupled stepwise in the desired order. An excess of each protected amino acid is generally used with an appropriate carboxyl group activator such as dicyclohexylcarbodiimide (DCC) in solution, for example, in methylene chloride (CH_2Cl_2), dimethyl formamide (DMF) mixtures.

After the desired amino acid sequence has been completed, the desired peptide is decoupled from the resin support by treatment with a reagent such as trifluoroacetic acid or hydrogen fluoride (HF), which not only cleaves the

peptide from the resin, but also cleaves all remaining side chain protecting groups. When the chloromethylated resin is used, hydrogen fluoride treatment results in the formation of the free peptide acids. When the benzhydrylamine resin is used, hydrogen fluoride treatment results directly in the free peptide amide. Alternatively, when the chloromethylated resin is employed, the side chain protected peptide can be decoupled by treatment of the peptide resin with ammonia to give the desired side chain protected amide or with an alkylamine to give a side chain protected alkylamide or dialkylamide. Side chain protection is then removed in the usual fashion by treatment with hydrogen fluoride to give the free amides, alkylamides, or dialkylamides.

These solid phase peptide synthesis procedures are well known in the art and further described in Stewart <u>Solid Phase Peptide Syntheses</u> (Freeman and Co., San Francisco, (1969)).

Using the "encoded synthetic library" or "very large scale immobilized polymer synthesis" system described in U.S. Patent Application Serial Nos. 07/492,462, filed March 7, 1990; 07/624,120, filed December 6, 1990; and 07/805,727, filed December 6, 1991; one can not only determine the minimum size of a peptide with such activity, one can also make all of the peptides that form the group of peptides that differ from the preferred motif (or the minimum size of that motif) in one, two, or more residues. This collection of peptides can then be screened for ability to bind to TPO-R. This immobilized polymer synthesis system or other peptide synthesis methods can also be used to synthesize truncation analogs and deletion analogs and combinationc of truncation and deletion analogs of all of the peptide compounds of the invention.

B. SYNTHETIC AMINO ACIDS

These procedures can also be used to synthesize peptides in which amino acids other than the 20 naturally occurring, genetically encoded amino acids are substituted at

one, two, or more positions of any of the compounds of the invention. For instance, naphthylalanine can be substituted for tryptophan, facilitating synthesis. Other synthetic amino acids that can be substituted into the peptides of the present invention include L-hydroxypropyl, L-3, 4-dihydroxyphenylalanyl, d amino acids such as L-d-hydroxylysyl and D-d-methylalanyl, L-a-methylalanyl, b amino acids, and isoquinolyl. D amino acids and non-naturally occurring synthetic amino acids can also be incorporated into the peptides of the present invention.

One can replace the naturally occurring side chains of the 20 genetically encoded amino acids (or D amino acids) with other side chains, for instance with groups such as alkyl, lower alkyl, cyclic 4-, 5-, 6-, to 7-membered alkyl, amide, amide lower alkyl, amide di(lower alkyl), lower alkoxy, hydroxy, carboxy and the lower ester derivatives thereof, and with 4-, 5-, 6-, to 7-membered hetereocyclic. In particular, proline analogs in which the ring size of the proline residue is changed from 5 members to 4, 6, or 7 members can be employed. Cyclic groups can be saturated or unsaturated, and if unsaturated, can be aromatic or non-aromatic.

Cyclic groups can be saturated or unsaturated, and if unsaturated, can be aromatic or non-aromatic. Heterocyclic groups preferably contain one or more nitrogen, oxygen, and/or sulphur heteroatoms. Examples of such groups include the furazanyl, furyl, imidazolidinyl, imidazolyl, imidazolinyl, isothiazolyl, isoxazolyl, morpholinyl (e.g. morpholino), oxazolyl, piperazinyl (e.g. 1-piperazinyl), piperidyl (e.g. 1-piperidyl, piperidino), pyranyl, pyrazinyl, pyrazolidinyl, pyrazolinyl, pyrazolyl, pyridazinyl, pyridyl, pyrimidinyl, pyrrolidinyl (e.g. 1-pyrrolidinyl), pyrrolinyl, pyrrolyl, thiadiazolyl, thiazolyl, thienyl, thiomorpholinyl (e.g. thiomorpholino), and triazolyl. These heterocyclic groups can be substituted or unsubstituted. Where a group is substituted, the substituent can be alkyl, alkoxy, halogen, oxygen, or substituted or unsubstituted phenyl.

One can also readily modify the peptides of the instant invention by phosphorylation, and other methods for

making peptide derivatives of the compounds of the present invention are described in Hruby et al.[42] Thus, the peptide compounds of the invention also serve as a basis to prepare peptide mimetics with similar biological activity.

The peptide compounds of the invention, including peptidomimetics, can be covalently modified to one or more of a variety of nonproteinaceous polymers, e.g., polyethylene glycol, polypropylene glycol, or polyoxyalkenes, in the manner set forth in U.S. Patent No. 4,640,835; U.S. Patent No. 4,496,689; U.S. Patent No. 4,301,144; U.S. Patent No. 4,670,417; U.S. Patent No. 4,791,192; or U.S. Patent No. 4,179,337, all which are incorporated by reference in their entirety herein.

C. TERMINAL MODIFICATIONS

Those of skill in the art recognize that a variety of techniques are available for constructing peptide mimetics with the same or similar desired biological activity as the corresponding peptide compound but with more favorable activity than the peptide with respect to solubility, stability, and susceptibility to hydrolysis and proteolysis. See, for example, Morgan and Gainor Ann. Rep. Med. Chem. 24:243-252 (1989). The following describes methods for preparing peptide mimetics modified at the N-terminal amino group, the C-terminal carboxyl group, and/or changing one or more of the amido linkages in the peptide to a non-amido linkage. It being understood that two or more such modifications can be coupled in one peptide mimetic structure (e.g., modification at the C-terminal carboxyl group and inclusion of a -CH_2-carbamate linkage between two amino acids in the peptide).

1. N-TERMINAL MODIFICATIONS

The peptides typically are synthesized as the free acid but, as noted above, could be readily prepared as the amide or ester. One can also modify the amino and/or carboxy

terminus of the peptide compounds of the invention to produce other compounds of the invention. Amino terminus modifications include methylating (i.e., -$NHCH_3$ or -$NH(CH_3)_2$), acetylating, adding a carbobenzoyl group, or blocking the amino terminus with any blocking group containing a carboxylate functionality defined by RCOO-, where R is selected from the group consisting of naphthyl, acridinyl, steroidyl, and similar groups. Carboxy terminus modifications include replacing the free acid with a carboxamide group or forming a cyclic lactam at the carboxy terminus to introduce structural constraints.

Amino terminus modifications are as recited above and include alkylating, acetylating, adding a carbobenzoyl group, forming a succinimide group, etc. Specifically, the N-terminal amino group can then be reacted as follows:

(a) to form an amide group of the formula RC(O)NH- where R is as defined above by reaction with an acid halide (e.g., RC(O)Cl) or acid anhydride. Typically, the reaction can be conducted by contacting about equimolar or excess amounts (e.g., about 5 equivalents) of an acid halide to the peptide in an inert diluent (e.g., dichloromethane) preferably containing an excess (e.g., about 10 equivalents) of a tertiary amine, such as diisopropylethylamine, to scavenge the acid generated during reaction. Reaction conditions are otherwise conventional (e.g., room temperature for 30 minutes). Alkylation of the terminal amino to provide for a lower alkyl N-substitution followed by reaction with an acid halide as described above will provide for N-alkyl amide group of the formula RC(O)NR-;

(b) to form a succinimide group by reaction with succinic anhydride. As before, an approximately equimolar amount or an excess of succinic anhydride (e.g., about 5 equivalents) can be employed and the amino group is converted to the succinimide by methods well known in the art including the use of an excess (e.g., ten equivalents) of a tertiary amine such as diisopropylethylamine in a suitable inert solvent (e.g., dichloromethane). See, for example, Wollenberg, et al., U.S. Patent No. 4,612,132 which is incorporated herein by reference in its entirety. It is

understood that the succinic group can be substituted with, for example, C_2-C_6 alkyl or -SR substituents which are prepared in a conventional manner to provide for substituted succinimide at the N-terminus of the peptide. Such alkyl substituents are prepared by reaction of a lower olefin (C_2-C_6) with maleic anhydride in the manner described by Wollenberg, et al., supra. and -SR substituents are prepared by reaction of RSH with maleic anhydride where R is as defined above;

(c) to form a benzyloxycarbonyl-NH- or a substituted benzyloxycarbonyl-NH- group by reaction with approximately an equivalent amount or an excess of CBZ-Cl (i.e., benzyloxycarbonyl chloride) or a substituted CBZ-Cl in a suitable inert diluent (e.g., dichloromethane) preferably containing a tertiary amine to scavenge the acid generated during the reaction;

(d) to form a sulfonamide group by reaction with an equivalent amount or an excess (e.g., 5 equivalents) of R-S(O)$_2$Cl in a suitable inert diluent (dichloromethane) to convert the terminal amine into a sulfonamide where R is as defined above. Preferably, the inert diluent contains excess tertiary amine (e.g., ten equivalents) such as diisopropylethylamine, to scavenge the acid generated during reaction. Reaction conditions are otherwise conventional (e.g., room temperature for 30 minutes);

(e) to form a carbamate group by reaction with an equivalent amount or an excess (e.g., 5 equivalents) of R-OC(O)Cl or R-OC(O)OC$_6$H$_4$-p-NO$_2$ in a suitable inert diluent (e.g., dichloromethane) to convert the terminal amine into a carbamate where R is as defined above. Preferably, the inert diluent contains an excess (e.g., about 10 equivalents) of a tertiary amine, such as diisopropylethylamine, to scavenge any acid generated during reaction. Reaction conditions are otherwise conventional (e.g., room temperature for 30 minutes); and

(f) to form a urea group by reaction with an equivalent amount or an excess (e.g., 5 equivalents) of R-N=C=O in a suitable inert diluent (e.g., dichloromethane) to

convert the terminal amine into a urea (i.e., RNHC(O)NH-) group where R is as defined above. Preferably, the inert diluent contains an excess (e.g., about 10 equivalents) of a tertiary amine, such as diisopropylethylamine. Reaction conditions are otherwise conventional (e.g., room temperature for about 30 minutes).

2. <u>C-TERMINAL MODIFICATIONS</u>

In preparing peptide mimetics wherein the C-terminal carboxyl group is replaced by an ester (i.e., -C(O)OR where R is as defined above), the resins used to prepare the peptide acids are employed, and the side chain protected peptide is cleaved with base and the appropriate alcohol, e.g., methanol. Side chain protecting groups are then removed in the usual fashion by treatment with hydrogen fluoride to obtain the desired ester.

In preparing peptide mimetics wherein the C-terminal carboxyl group is replaced by the amide -C(O)NR^{3}R^4, a benzhydrylamine resin is used as the solid support for peptide synthesis. Upon completion of the synthesis, hydrogen fluoride treatment to release the peptide from the support results directly in the free peptide amide (i.e., the C-terminus is -C(O)NH$_2$). Alternatively, use of the chloromethylated resin during peptide synthesis coupled with reaction with ammonia to cleave the side chain protected peptide from the support yields the free peptide amide and reaction with an alkylamine or a dialkylamine yields a side chain protected alkylamide or dialkylamide (i.e., the C-terminus is -C(O)NRR^1 where R and R^1 are as defined above). Side chain protection is then removed in the usual fashion by treatment with hydrogen fluoride to give the free amides, alkylamides, or dialkylamides.

In another alternative embodiment, the C-terminal carboxyl group or a C-terminal ester can be induced to cyclize by internal displacement of the -OH or the ester (-OR) of the carboxyl group or ester respectively with the N-terminal amino group to form a cyclic peptide. For example, after synthesis

and cleavage to give the peptide acid, the free acid is converted to an activated ester by an appropriate carboxyl group activator such as dicyclohexylcarbodiimide (DCC) in solution, for example, in methylene chloride (CH_2Cl_2), dimethyl formamide (DMF) mixtures. The cyclic peptide is then formed by internal displacement of the activated ester with the N-terminal amine. Internal cyclization as opposed to polymerization can be enhanced by use of very dilute solutions. Such methods are well known in the art.

One can also cyclize the peptides of the invention, or incorporate a desamino or descarboxy residue at the terminii of the peptide, so that there is no terminal amino or carboxyl group, to decrease susceptibility to proteases or to restrict the conformation of the peptide. C-terminal functional groups of the compounds of the present invention include amide, amide lower alkyl, amide di(lower alkyl), lower alkoxy, hydroxy, and carboxy, and the lower ester derivatives thereof, and the pharmaceutically acceptable salts thereof.

D. BACKBONE MODIFICATIONS

Other methods for making peptide derivatives of the compounds of the present invention are described in Hruby et al. Biochem J. 268(2):249-262 (1990), incorporated herein by reference. Thus, the peptide compounds of the invention also serve as structural models for non-peptidic compounds with similar biological activity. Those of skill in the art recognize that a variety of techniques are available for constructing compounds with the same or similar desired biological activity as the lead peptide compound but with more favorable activity than the lead with respect to solubility, stability, and susceptibility to hydrolysis and proteolysis. See Morgan and Gainor Ann. Rep. Med. Chem. 24:243-252 (1989), incorporated herein by reference. These techniques include replacing the peptide backbone with a backbone composed of phosphonates, amidates, carbamates, sulfonamides, secondary amines, and N-methylamino acids.

Peptide mimetics wherein one or more of the peptidyl linkages [-C(O)NH-] have been replaced by such linkages as a $-CH_2$-carbamate linkage, a phosphonate linkage, a $-CH_2$-sulfonamide linkage, a urea linkage, a secondary amine ($-CH_2NH-$) linkage, and an alkylated peptidyl linkage [$-C(O)NR^6-$ where R^6 is lower alkyl] are prepared during conventional peptide synthesis by merely substituting a suitably protected amino acid analogue for the amino acid reagent at the appropriate point during synthesis.

Suitable reagents include, for example, amino acid analogues wherein the carboxyl group of the amino acid has been replaced with a moiety suitable for forming one of the above linkages. For example, if one desires to replace a -C(O)NR- linkage in the peptide with a $-CH_2$-carbamate linkage ($-CH_2OC(O)NR-$), then the carboxyl (-COOH) group of a suitably protected amino acid is first reduced to the $-CH_2OH$ group which is then converted by conventional methods to a -OC(O)Cl functionality or a para-nitrocarbonate $-OC(O)O-C_6H_4-p-NO_2$ functionality. Reaction of either of such functional groups with the free amine or an alkylated amine on the N-terminus of the partially fabricated peptide found on the solid support leads to the formation of a $-CH_2OC(O)NR-$ linkage. For a more detailed description of the formation of such $-CH_2$-carbamate linkages, see Cho et al Science, 261:1303-1305 (1993).

Similarly, replacement of an amido linkage in the peptide with a phosphonate linkage can be achieved in the manner set forth in U.S. Patent Application Serial Nos. 07/943,805, 08/081,577, and 08/119,700, the disclosures of which are incorporated herein by reference in their entirety.

Replacement of an amido linkage in the peptide with a $-CH_2$-sulfonamide linkage can be achieved by reducing the carboxyl (-COOH) group of a suitably protected amino acid to the $-CH_2OH$ group and the hydroxyl group is then converted to a suitable leaving group such as a tosyl group by conventional methods. Reaction of the tosylated derivative with, for example, thioacetic acid followed by hydrolysis and oxidative chlorination will provide for the $-CH_2-S(O)_2Cl$ functional group which replaces the carboxyl group of the otherwise

suitably protected amino acid. Use of this suitably protected amino acid analogue in peptide synthesis provides for inclusion of an $-CH_2S(O)_2NR-$ linkage which replaces the amido linkage in the peptide thereby providing a peptide mimetic. For a more complete description on the conversion of the carboxyl group of the amino acid to a $-CH_2S(O)_2Cl$ group, see, for example, Weinstein, Boris Chemistry & Biochemistry of Amino Acids, Peptides and Proteins Vol. 7, pp. 267-357, Marcel Dekker, Inc., New York (1983) which is incorporated herein by reference.

Replacement of an amido linkage in the peptide with a urea linkage can be achieved in the manner set forth in U.S. Patent Application Serial No. 08/147,805 which application is incorporated herein by reference in its entirety.

Secondary amine linkages wherein a $-CH_2NH-$ linkage replaces the amido linkage in the peptide can be prepared by employing, for example, a suitably protected dipeptide analogue wherein the carbonyl bond of the amido linkage has been reduced to a CH_2 group by conventional methods. For example, in the case of diglycine, reduction of the amide to the amine will yield after deprotection $H_2NCH_2CH_2NHCH_2COOH$ which is then used in N-protected form in the next coupling reaction. The preparation of such analogues by reduction of the carbonyl group of the amido linkage in the dipeptide is well known in the art.

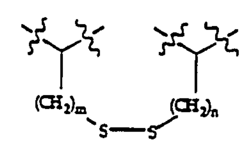
The suitably protected amino acid analogue is employed in the conventional peptide synthesis in the same manner as would the corresponding amino acid. For example, typically about 3 equivalents of the protected amino acid analogue are employed in this reaction. An inert organic diluent such as methylene chloride or DMF is employed and, when an acid is generated as a reaction by-product, the reaction solvent will typically contain an excess amount of a tertiary amine to scavenge the acid generated during the reaction. One particularly preferred tertiary amine is diisopropylethylamine which is typically employed in about 10 fold excess. The reaction results in incorporation into the peptide mimetic of an amino acid analogue having a

non-peptidyl linkage. Such substitution can be repeated as desired such that from zero to all of the amido bonds in the peptide have been replaced by non-amido bonds.

One can also cyclize the peptides of the invention, or incorporate a desamino or descarboxy residue at the terminii of the peptide, so that there is no terminal amino or carboxyl group, to decrease susceptibility to proteases or to restrict the conformation of the peptide. C-terminal functional groups of the compounds of the present invention include amide, amide lower alkyl, amide di(lower alkyl), lower alkoxy, hydroxy, and carboxy, and the lower ester derivatives thereof, and the pharmaceutically acceptable salts thereof. Examples of cyclized compounds are provided in Tables 4, 5, 6, 8, and 9.

E. DISULFIDE BOND FORMATION

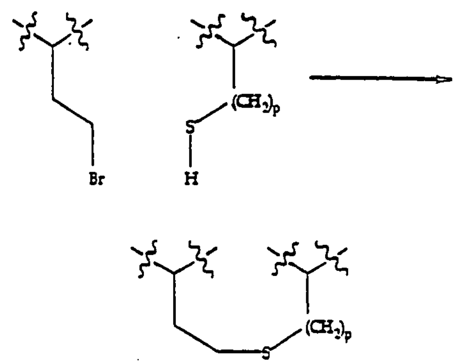
The compounds of the present invention may exist in a cyclized form with an intramolecular disulfide bond between the thiol groups of the cysteines . Alternatively, an intermolecular disulfide bond between the thiol groups of the cysteines can be produced to yield a dimeric (or higher oligomeric) compound. One or more of the cysteine residues may also be substituted with a homocysteine. These intramolecular or intermolecular disulfide derivatives can be represented schematically as shown below:



wherein m and n are independently 1 or 2.

Other embodiments of this invention provide for analogs of these disulfide derivatives in which one of the

sulfurs has been replaced by a CH_2 group or other isostere for sulfur. These analogs can be made via an intramolecular or intermolecular displacement, using methods known in the art as shown below:



wherein p is 1 or 2. One of skill in the art will readily appreciate that this displacement can also occur using other homologs of the a-amino-g-butyric acid derivative shown above and homocysteine.

Alternatively, the amino-terminus of the peptide can be capped with an alpha-substituted acetic acid, wherein the alpha substituent is a leaving group, such as an a-haloacetic acid, for example, a-chloroacetic acid, a-bromoacetic acid, or a-iodoacetic acid. The compounds of the present invention can be cyclized or dimerized via displacement of the leaving group by the sulfur of the cysteine or homocysteine residue. See, e.g., Barker et al. J. Med. Chem. 35:2040-2048 (1992) and Or et al. J. Org. Chem. 56:3146-3149 (1991), each of which is incorporated herein by reference. Examples of dimerized compounds are provided in Tables 7, 9, and 10.

V. UTILITY

The compounds of the invention are useful *in vitro* as unique tools for understanding the biological role of TPO, including the evaluation of the many factors thought to influence, and be influenced by, the production of TPO and the

receptor binding process. The present compounds are also useful in the development of other compounds that bind to and activate the TPO-R, because the present compounds provide important information on the relationship between structure and activity that should facilitate such development.

The compounds are also useful as competitive binders in assays to screen for new TPO receptor agonists. In such assay embodiments, the compounds of the invention can be used without modification or can be modified in a variety of ways; for example, by labeling, such as covalently or non-covalently joining a moiety which directly or indirectly provides a detectable signal. In any of these assays, the materials thereto can be labeled either directly or indirectly. Possibilities for direct labeling include label groups such as: radiolabels such as ^{125}I, enzymes (US Patent 3,645,090) such as peroxidase and alkaline phosphatase, and fluorescent labels (U.S. Patent Np. 3,940,475) capable of monitoring the change in fluorescence intensity, wavelength shift, or fluorescence polarization. Possibilities for indirect labeling include biotinylation of one constituent followed by binding to avidin coupled to one of the above label groups. The compounds may also include spacers or linkers in cases where the compounds are to be attached to a solid support.

Moreover, based on their ability to bind to the TPO receptor, the peptides of the present invention can be used as reagents for detecting TPO receptors on living cells, fixed cells, in biological fluids, in tissue homogenates, in purified, natural biological materials, etc. For example, by labelling such peptides, one can identify cells having TPO-R on their surfaces. In addition, based on their ability to bind the TPO receptor, the peptides of the present invention can be used in *in situ* staining, FACS (fluorescence-activated cell sorting), Western blotting, ELISA, etc. In addition, based on their ability to bind to the TPO receptor, the peptides of the present invention can be used in receptor purification, or in purifying cells expressing TPO receptors on the cell surface (or inside permeabilized cells).

The compounds of the present invention can also be utilized as commercial reagents for various medical research and diagnostic uses. Such uses include but are not limited to: (1) use as a calibration standard for quantitating the activities of candidate TPO agonists in a variety of functional assays; (2) use to maintain the proliferation and growth of TPO-dependent cell lines; (3) use in structural analysis of the TPO-receptor through co-crystallization; (4) use to investigate the mechanism of TPO signal transduction/receptor activation; and (5) other research and diagnostic applications wherein the TPO-receptor is preferably activated or such activation is conveniently calibrated against a known quantity of a TPO agonist, and the like.

The compounds of the present invention can be used for the *in vitro* expansion of megakaryocytes and their committed progenitors, both in conjunction with additional cytokines or on their own. See, e.g., DiGiusto et al. PCT Publication No. 95/05843, which is incorporated herein by reference. Chemotherapy and radiation therapies cause thrombocytopenia by killing the rapidly dividing, more mature population of megakaryocytes. However, these therapeutic treatments can also reduce the number and viability of the immature, less mitotically active megakaryocyte precursor cells. Thus, amelioration of the thrombocytopenia by TPO or the compounds of the present invention can be hastened by infusing patients post chemotherapy or radiation therapy with a population of his or her own cells enriched for megakaryocytes and immature precursors by *in vitro* culture.

The compounds of the invention can also be administered to warm blooded animals, including humans, to activate the TPO-R *in vivo*. Thus, the present invention encompasses methods for therapeutic treatment of TPO related disorders that comprise administering a compound of the invention in amounts sufficient to mimic the effect of TPO on TPO-R *in vivo*. For example, the peptides and compounds of the invention can be administered to treat a variety of hematological disorders, including but not limited to platelet disorders and thrombocytopenia, particularly when associated

with bone marrow transfusions, radiation therapy, and chemotherapy.

In some embodiments of the invention, TPO antagonists are preferably first administered to patients undergoing chemotherapy or radiation therapy, followed by administration of the tpo agonists of the invention.

The activity of the compounds of the present invention can be evaluated either *in vitro* or *in vivo* in one of the numerous models described in McDonald Am. J. of Pediatric Hematology/Oncology 14:8-21 (1992), which is incorporated herein by reference.

According to one embodiment, the compositions of the present invention are useful for treating thrombocytopenia associated with bone marrow transfusions, radiation therapy, or chemotherapy. The compounds typically will be administered prophylactically prior to chemotherapy, radiation therapy, or bone marrow transplant or after such exposure.

Accordingly, the present invention also provides pharmaceutical compositions comprising, as an active ingredient, at least one of the peptides or peptide mimetics of the invention in association with a pharmaceutical carrier or diluent. The compounds of this invention can be administered by oral, pulmonary, parental (intramuscular, intraperitoneal, intravenous (IV) or subcutaneous injection), inhalation (via a fine powder formulation), transdermal, nasal, vaginal, rectal, or sublingual routes of administration and can be formulated in dosage forms appropriate for each route of administration. See, e.g., Bernstein et al. PCT Patent Publication No. WO 93/25221; Pitt et al. PCT Patent Publication No. WO 94/17784; and Pitt et al. European Patent Application 613,683, each of which is incorporated herein by reference.

Solid dosage forms for oral administration include capsules, tablets, pills, powders, and granules. In such solid dosage forms, the active compound is admixed with at least one inert pharmaceutically acceptable carrier such as sucrose, lactose, or starch. Such dosage forms can also comprise, as is normal practice, additional substances other

than inert diluents, e.g., lubricating agents such as magnesium stearate. In the case of capsules, tablets, and pills, the dosage forms may also comprise buffering agents. Tablets and pills can additionally be prepared with enteric coatings.

Liquid dosage forms for oral administration include pharmaceutically acceptable emulsions, solutions, suspensions, syrups, with the elixirs containing inert diluents commonly used in the art, such as water. Besides such inert diluents, compositions can also include adjuvants, such as wetting agents, emulsifying and suspending agents, and sweetening, flavoring, and perfuming agents.

Preparations according to this invention for parental administration include sterile aqueous or non-aqueous solutions, suspensions, or emulsions. Examples of non-aqueous solvents or vehicles are propylene glycol, polyethylene glycol, vegetable oils, such as olive oil and corn oil, gelatin, and injectable organic esters such as ethyl oleate. Such dosage forms may also contain adjuvants such as preserving, wetting, emulsifying, and dispersing agents. They may be sterilized by, for example, filtration through a bacteria retaining filter, by incorporating sterilizing agents into the compositions, by irradiating the compositions, or by heating the compositions. They can also be manufactured using sterile water, or some other sterile injectable medium, immediately before use.

Compositions for rectal or vaginal administration are preferably suppositories which may contain, in addition to the active substance, excipients such as cocoa butter or a suppository wax. Compositions for nasal or sublingual administration are also prepared with standard excipients well known in the art.

The compositions containing the compounds can be administered for prophylactic and/or therapeutic treatments. In therapeutic applications, compositions are administered to a patient already suffering from a disease, as described above, in an amount sufficient to cure or at least partially arrest the symptoms of the disease and its complications. An

amount adequate to accomplish this is defined as "therapeutically effective dose". Amounts effective for this use will depend on the severity of the disease and the weight and general state of the patient.

The compositions of the invention can also be microencapsulated by, for example, the method of Tice and Bibi (in Treatise on Controlled Drug Delivery, ed. A. Kydonieus, Marcel Dekker, N.Y. (1992), pp. 315-339).

In prophylactic applications, compositions containing the compounds of the invention are administered to a patient susceptible to or otherwise at risk of a particular disease. Such an amount is defined to be a "prophylactically effective dose". In this use, the precise amounts again depend on the patient's state of health and weight.

The quantities of the TPO agonist necessary for effective therapy will depend upon many different factors, including means of administration, target site, physiological state of the patient, and other medicants administered. Thus, treatment dosages should be titrated to optimize safety and efficacy. Typically, dosages used *in vitro* may provide useful guidance in the amounts useful for in situ administration of these reagents. Animal testing of effective doses for treatment of particular disorders will provide further predictive indication of human dosage. Various considerations are described, e.g., in Gilman et al. (eds), Goodman and Gilman's: The Pharmacological Basis of Therapeutics, 8th ed., Pergamon Press (1990); and Remington's Pharmaceutical Sciences, 7th ed., Mack Publishing Co., Easton, Penn. (1985); each of which is hereby incorporated by reference.

The peptides and peptide mimetics of this invention are effective in treating TPO mediated conditions when administered at a dosage range of from about 0.001 mg to about 10 mg/kg of body weight per day. The specific dose employed is regulated by the particular condition being treated, the route of administration as well as by the judgement of the attending clinician depending upon factors such as the severity of the condition, the age and general condition of the patient, and the like.

Although only preferred embodiments of the invention are specifically described above, it will be appreciated that modifications and variations of the invention are possible without departing from the spirit and intended scope of the invention.

EXAMPLE 1
SOLID PHASE PEPTIDE SYNTHESIS

Various peptides of the invention were synthesized using the Merrifield solid phase synthesis techniques (See Steward and Young, Solid Phase Peptide Synthesis, 2d. edition, Pierce Chemical, Rockford, IL (1984) and Merrifield J. Am. Chem. Soc. 85:2149 (1963)) on a Milligen/Biosearch 9600 automated instrument or an Applied Biosystems Inc. Model 431A peptide synthesizer. The peptides were assembled using standard protocols of the Applied Biosystems Inc. System Software version 1.01. Each coupling was performed for one-two hours with BOP (benzotriazolyl N-oxtrisdimethylaminophosphonium hexafluorophosphate) and HOBt (1-hydroxybenzotriazole).

The resin used was HMP resin or PAL (Milligen/Biosearch), which is a cross-linked polystyrene resin with 5-(4'-Fmoc-aminomethyl-3,5'-dimethyoxyphenoxy) valeric acid as a linker. Use of PAL resin results in a carboxyl terminal amide functionality upon cleavage of the peptide from the resin. Upon cleavage, the HMP resin produces a carboxylic acid moiety at the C-terminus of the final product. Most reagents, resins, and protected amino acids (free or on the resin) were purchased from Millipore or Applied Biosystems Inc.

The Fmoc group was used for amino protection during the coupling procedure. Primary amine protection on amino acids was achieved with Fmoc and side chain protection groups were t-butyl for serine, tyrosine, asparagine, glutamic acid, and threonine; trityl for glutamine; Pmc (2,2,5,7,8-pentamethylchroma sulfonate) for arginine;

N-t-butyloxycarbonyl for tryptophan; N-trityl for histidine and glutamine; and S-trityl for cysteine.

Removal of the peptides from the resin and simultaneous deprotection of the side chain functions were achieved by treatment with reagent K or slight modifications of it. Alternatively, in the synthesis of those peptides, with an amidated carboxyl terminus, the fully assembled peptide was cleaved with a mixture of 90% trifluoroacetic acid, 5% ethanedithiol, and 5% water, initially at 4°C, and gradually increasing to room temperature. The deprotected peptides were precipitated with diethyl ether. In all cases, purification was by preparative, reverse-phase, high performance liquid chromatography on a C_{18} bonded silica gel column with a gradient of acetonitrile/water in 0.1% trifluoroacetic acid. The homogeneous peptides were characterized by Fast Atom Bombardment mass spectrometry or electrospray mass spectrometry and amino acid analysis when applicable.

EXAMPLE 2
BIOASSAYS

Bioactivity of the peptides can be measured using a thrombopoietin dependent cell proliferation assay. Murine IL-3 dependent Ba/F3 cells were transfected with full length human TPO-R. In the absence of IL-3 (WEHI-3 conditioned media), these cells are dependent on TPO for proliferation. The parental, untransfected cell line does not respond to human TPO, but remains IL-3 dependent.

Bioassays have been performed on both of the above cell lines using synthetic peptides derived from library screening. The cells were grown in complete RPMI-10 media, containing 10% WEHI-3 conditioned media, then washed twice in PBS, resuspended in media which lacked WEHI-3 conditioned media, and added to wells containing dilutions of peptide or TPO at 2 x 10^4 cells/well. The cells were incubated for 48 hours at 37°C in a humidified 5% CO_2 atmosphere and metabolic activity was assayed by the reduction of MTT to formazan, with

absorbance at 570 nM measured on an ELISA plate reader. The peptides tested stimulated proliferation of TPO-R transfected Ba/F3 cells in a dose dependent manner as shown in Figure 1. These peptides have no effect on the parental cell line.

EXAMPLE 3
BINDING AFFINITY

Binding affinities of chemically synthesized peptides for TPO-R were measured in a competition binding assay. The wells of a microtiter plate were coated with 1 mg streptavidin, blocked with PBS/1% BSA, followed by 50 ng of biotinylated anti-receptor immobilizing antibody (Ab179). The wells were then treated with a 1:10 dilution of soluble TPO-R harvest. Various concentrations of peptide or peptide mimetic were mixed with a constant amount of a truncated form of TPO consisting of residues 1-156 fused to the C-terminus of maltose binding protein ($MBP-TPO_{156}$). The peptide $MBP-TPO_{156}$ mixtures were added to the TPO-R coated wells, incubated for 2 hours at 4°C and then washed with PBS. The amount of $MBP-TPO_{156}$ that was bound at equilibrium was measured by adding a rabbit anti-sera directed against MBP, followed by alkaline phosphatase conjugated goat anti-rabbit IgG. The amount of alkaline phosphatase in each well was then determined using standard methods.

The assay is conducted over a range of peptide concentrations and the results are graphed such that the y axis represents the amount of bound $MBP-TPO_{156}$ and the x axis represents the concentration of peptide or peptide mimetic. One can then determine the concentration at which the peptide or peptide mimetic will reduce by 50% (IC_{50}) the amount of $MBP-TPO_{156}$ bound to immobilized TPO-R. The dissociation constant (Kd) for the peptide should be similar to the measured IC_{50} using the assay conditions described above.

EXAMPLE 4
"PEPTIDES ON PLASMIDS"

The pJS142 vector is used for library construction and is shown in Figure 4. Three oligonucleotide sequences are needed for library construction: ON-829 (5' ACC ACC TCC GG); ON-830 (5' TTA CTT AGT TA) and a library specific oligonucleotide of interest (5' GA GGT GGT $\{NNK\}_n$ TAA CTA AGT AAA GC), where $\{NNK\}_n$ denotes a random region of the desired length and sequence. The oligonucleotides can be 5' phosphorylated chemically during synthesis or after purification with polynucleotide kinase. They are then annealed at a 1:1:1 molar ratio and ligated to the vector.

The strain of *E. coli* which is preferably used for panning has the genotype: *Δ(srl-recA) endA1 nupG lon-11 sulA1 hsdR17 Δ(ompT-fepC)266 ΔclpA319::kan ΔlacI lac ZU118* which can be prepared from an *E. coli* strain from the *E. coli* Genetic Stock Center at Yale University (*E. coli* b/r, stock center designation CGSC:6573) with genotype *lon-11 sulA1*. The above *E. coli* strain is prepared for use in electroporation as described by Dower et al. Nucleic Acids Res. 16:6127 (1988), except that 10% glycerol is used for all wash steps. The cells are tested for efficiency using 1 pg of a Bluescript plasmid (Stratagene). These cells are used for growth of the original library and for amplification of the enriched population after each round of panning.

Peptides on plasmids are released from cells for panning by gentle enzymatic digestion of the cell wall using lysozyme. After pelleting of the cell debris, the crude lysate can be used directly on most receptors. If some additional purification of the plasmid complexes is needed, a gel filtration column can be used to remove many of the low molecular weight contaminants in the crude lysate.

Panning is carried out in a buffer (HEKL) of a lower salt concentration than most physiological buffers. The panning can be conducted in microtiter wells with a receptor immobilized on a nonblocking monoclonal antibody (MAb) or by panning on beads or on columns. More specifically, in the

first round of panning, 24 wells, each coated with receptor, can be used. For the second round, six wells coated with receptor (PAN sample) and 6 wells without receptor (NC sample) are typically used. Comparison of the number of plasmids in these two samples can give an indication of whether receptor specific clones are being enriched by panning. "Enrichment" is defined as the ratio of PAN transformants to those recovered from the NC sample. Enrichment of 10 fold is usually an indication that receptor specific clones are present.

In later rounds of panning, it is useful to reduce the input of lysate into the wells to lower nonspecific background binding of the plasmid complexes. In round 2, usually 100 μl of lysate per well is used. In round 3, 100 μl of lysate per well diluted with 1/10 in HEKL/BSA is used. For further rounds of panning, typically an input of plasmid transforming units of at least 1000 fold above the estimated remaining diversity is used.

The binding properties of the peptides encoded by individual clones are typically examined after 3, 4, or 5 rounds of panning, depending on the enrichment numbers observed. Typically, an ELISA that detects receptor specific binding by LacI-peptide fusion proteins is used. LacI is normally a tetramer and the minimum functional DNA binding species is a dimer. The peptides are thus displayed multivalently on the fusion protein. Assuming that a sufficient density of receptor can be immobilized in wells, the peptides fused to LacI will bind to the surface in a cooperative, multivalent fashion. This cooperative binding permits the detection of binding events of low intrinsic affinity. The sensitivity of this assay is an advantage in that initial hits of low affinity can be easily identified, but is a disadvantage in that the signal in the ELISA is not correlated with the intrinsic affinity of the peptides. Fusion of the peptides to maltose binding protein (MBP) as described below permits testing in an ELISA format where signal strength is better correlated with affinity. See Figure 5A-B.

DNA from clones of interest can be prepared in double stranded form using any standard miniprep procedure. The coding sequences of interesting single clones or populations of clones can be transferred to vectors that fuse those sequences in frame with the gene encoding MBP, a protein that generally occurs as a monomer in solution. The cloning of a library into pJS142 creates a BspEI restriction site near the beginning of the random coding region of the library. Digestion with BspEI and ScaI allows the purification of a ~900 bp DNA fragment that can be subcloned into one of two vectors, pELM3 (cytoplasmic) or pELM15 (periplasmic), which are simple modifications of the pMALc2 and pMALp2 vectors, respectively, available commercially from New England Biolabs. See Figure 5A-B. Digestion of pELM3 and pELM15 with AgeI and ScaI allows efficient cloning of the BspEI-ScaI fragment from the pJS142 library. The BspEI and AgeI ends are compatible for ligation. In addition, correct ligation of the ScaI sites is essential to recreate a functional *bla* (Amp resistance) gene, thus lowering the level of background clones from undesired ligation events. Expression of the *tac* promoter-driven MBP-peptide fusions can then be induced with IPTG.

Lysates for the LacI or MBP ELISAs are prepared from individual clones by lysing cells using lysozyme and removing insoluble cell debris by centrifugation. The lysates are then added to wells containing immobilized receptor and to control wells without receptor. Binding by the LacI or MBP peptide fusions is detected by incubation with a rabbit polyclonal antiserum directed against either LacI or MBP followed by incubation with alkaline phosphatase labeled goat anti rabbit second antibody. The bound alkaline phosphatase is detected with p-nitrophenyl phosphate chromagenic substrate.

EXAMPLE 5
"HEADPIECE DIMER" SYSTEM

A variant of the LacI peptides-on-plasmids technique utilizes a DNA binding protein called "headpiece dimer". DNA binding by the *E. coli lac* repressor is mediated by the approximately 60 amino acid "headpiece" domain. The dimer of the headpiece domains that binds to the *lac* operator is normally formed by association of the much larger approximately 300 amino acid C-terminal domain. The "headpiece dimer" system utilizes headpiece dimer molecules containing two headpieces connected via short peptide linker. These proteins bind DNA with sufficient stability to allow association of a peptide epitope displayed at the C-terminus of the headpiece dimer with the plasmid encoding that peptide.

The random peptides are fused to the C-terminus of the headpiece dimer, which binds to the plasmid that encoded it to make a peptide-headpiece dimer-plasmid complex that can be screened by panning. The headpiece dimer peptides-on-plasmids system allows greater selectivity for high affinity ligands than the LacI system. Thus, the headpiece dimer system is useful for making mutagenesis libraries based on initial low-affinity hits, and selecting higher affinity variants of those initial sequences.

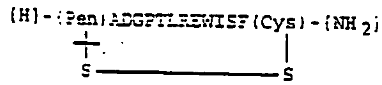
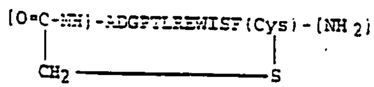
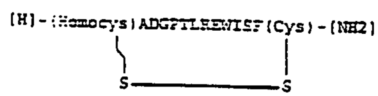
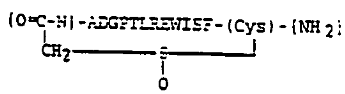
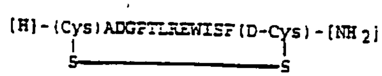
The libraries are constructed as with peptides on plasmids using headpiece dimer vector pCMG14 (see Figure 6A-C). The presence of the *lac* operator is not required for plasmid binding by the headpiece dimer protein. The libraries were introduced into bacterial strain comprising *E. coli (lon-11 sulA1 hsdR17 (ompT-fepC) ΔclpA319::kan ΔlacI lac ZU118 Δ(srl-recA) 306::Tn10* .and amplified under conditions of basal (A) promoter induction. Panning of headpiece dimer libraries is carried out by similar procedures to those used for LacI libraries, except that HEK buffer is used instead of HEKL buffer and elution of plasmids from the wells is performed with aqueous phenol instead of with IPTG. Sequences from headpiece dimer panning are often characterized after transfer to the MBP vector so that they can be tested in the

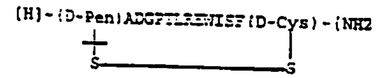
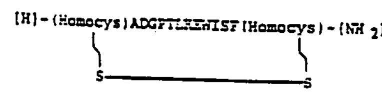
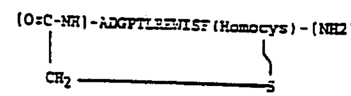
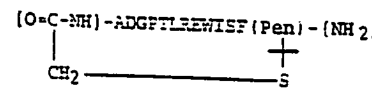
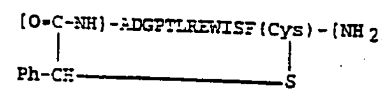
affinity sensitive MBP ELISA and also so that populations of clones can be screened by colony lifts with labeled receptor.

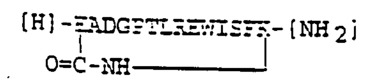
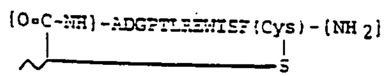
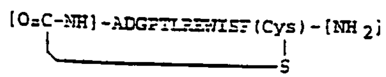
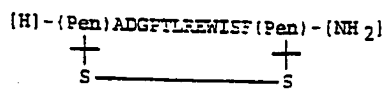
EXAMPLE 6

In this example cyclized compounds were subjected to three assays. First, IC_{50} valves were obtained as described above. Additionally, an MTT cell proliferation assay as described above was performed to calculate EC_{50} values. Finally, a microphysiometer (Molecular Devices Corp.) assay was performed. Basically, in this assay the rate of acidification of the extracellular medium in response to TPO receptor stimulation by the compounds of the invention was determined. The ranges for EC_{50} are symbolically indicated as for IC_{50} described above. The results are summarized in Table 4.

TABLE 4

Structure	EC50(nM) Proliferation	EC50(nM) Microphys.	IC50(nM)
	++	++	++
	++	++	+-
	++	++	ND
	+-	+-	+-
	+-	+-	ND
	+-	+	++

Structure	EC50(nM) Proliferation	EC50(nM) Microphys.	IC50(nM)
	+	+	++
	+	+	++
	+-	+	++
	+	+-	+-
	++	+-	++
	+-	+-	ND

Structure	EC50(nM) Proliferation	EC50(nM) Microphys.	IC50(nM)
	+	+	ND
	++	+	ND
	++	+-	ND
	+-	+-	+-
	+-	+-	ND

EXAMPLE 7

In this example amino acid substitutes at positions D, E, I, S, or F in the cyclized compound

C A D G P T L R E W I S F C

were assayed for EC_{50} and IC_{50} values as described above. Microphysiometer results are given in parentheses. The results are summarized in Table 5 below.

TABLE 5

CADGPTLREWISFC

Substitution	EC50 (nM) Cell Prolif.	IC50 (nM)
E - Q	++ (+)	++
D - A	+ (+)	++
I - A	+ (+)	+
S - A	++ (++)	++
S - D-Ala	+	+
S - Sar	+	++
S - Aib	++ (+)	++
S - D-Ser	++	++
S - Nva	++ (++)	++
S - Abu	++	++
S - (N-Me-Ala)	+	+
S - (N-Me-Val)	+	+
S - (N-Me-Ala) *	+	+
S - (Nor-Leu)	++	++
S - (t-Bu-Gly)	+	++
S - [N-Me-Ser(Bzl)]		+

Substitution	EC50 (nM) Cell Prolif.	IC50 (nM)
S - (Homoser)	ND	ND
S - (N-Me-Leu)	+	ND
F - A	+ (+)	++
F - D-Ala	+	++
F - D-Phe	+	++
F - Homo-Phe	++ (++)	++
F - CHA	++ (++)	++
F - Thi	++	++
F - (Ser(Bzl))	++	++
F - (N-Me-Ala)	+	+
F - (Phenyigly)	++ (++)	++
F - (Pyridylala)	++	++
F - (p-Nitrophe)	++ (++)	++
F - (3,4-di-Cl-Phe)	++ (+)	++
F - (p-Cl-Phe)	++	++
F - (2-Nal)	++ (++)	++
F - (1-Nal)	++	++
F - (DiPh - Ala)	++	++

Substitution	EC50 (nM) Cell Prolif.	IC50 (nM)
F - (N-Me-Phe)	++	ND
S,F - Ava (thioether)	+-	++
S,F - Ava (cys-cys)	+	++
S,F - Ava	+-	++
AD - deletion	+-(+)	ND
ADG - deletion	(+)	+-

Ava = H_2N  COOH

EXAMPLE 8

In this example, amino acid substitutions in the compound

[O = C - NH] - A D G P T L R E W I S F (CYS)

CH_2 ———————————————— S

were evaluated at positions D, S, or F as indicated in Table 6 below. EC_{50} and IC_{50} values were calculated as described above. Microphysiometer results are in parentheses.

TABLE 6

```
[O=C-NH]-ADGPTLREWISF(Cys)
   |                   |
  CH2------------------S
```

Substitution	EC50 (nM) Cell Prolif.	IC50 (nM)
D - E	(-)	ND
free acid form	++ (+)	ND
C-term. Gly addition	++	++
S - Abu	++(++)	ND
F - DiPh-Ala	(++)	++
S,F - Abu, DiPh-Ala	+(+)	++

EXAMPLE 9

In this example EC_{50} and IC_{50} values were calculated as described above for the dimer compounds listed in Table 7 below. The cyclized monomer

```
C A D G P T L R E W I S F C
|_________________________|
```

is included as a comparison.

The compounds of Table 8 were inactive at the maximum concentration tested of 10μm.

In Table 9, EC_{50} and IC_{50} values determined as described above for cyclized and dimerized variants of I E G P T L R Q W L A A R A are compared.

In Table 10, truncations of the dimer

```
      (H) - I E G P T L R Q W L A A R A
                                       |
(H) - I E G P T L R Q W L A A R A (βala) K - (NH2)
```

are compared. EC_{50} and IC_{50} values were calculated as described above. Microphysiometer results are given in parentheses.

TABLE 7

	EC50 (nM) Micronys.	EC50 (nM) Prolif.	IC50 (nM)
[Br-C(=O)-NH]-ADGPTLREWISFC-[NH2] [Br-C(=O)-NH]-ADGPTLREWISFC-[NH2]	++	++	++
[H]-IEGPTLRQWLAARA [H]-IEGPTLRQWLAARA(β-Ala)K-[NH2]	++	++	++
[H]-CIEGPTLRQWLAARA-[NH2] [H]-CIEGPTLRQWLAARA-[NH2]	++	++	++
[H]-CADGPTLREWISF-[NH2] [H]-CADGPTLREWISF-[NH2]	++	++	++
[H]-SVQCGPTLRQWLAARNHLS-[NH2] [H]-SVQCGPTLRQWLAARNHLS-[NH2]	++	++	++
[H]-MVGPTLRSGC-[NH2] [H]-MVGPTLRSGC-[NH2]	ND	+	+

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	EC50 (nM) Micronys.	EC50 (nM) Prolif.	IC50 (nM)
CADGPTLREWISFC	++	++	++
[Ac]-ADGPTLREWISFC [Ac]-ADGPTLREWISFC	ND	++	++
ADGPTLREWISFC ADGPTLREWISFC	++	++	++
[Ac]-DGPTLREWISFC [Ac]-DGPTLREWISFC	++	++	++
[Ac]-GPTLREWISFC [Ac]-GPTLREWISFC	ND	++	++
GPTLREWISFC GPTLREWISFC	++	++	+
[Ac]-PTLREWISFC [Ac]-PTLREWISFC	ND	++	++
PTLREWISFC PTLREWISFC	++	++	+-
[Ac]-TLREWISFC [Ac]-TLREWISFC	+-	+-	+-
TLREWISFC TLREWISFC	++	+-	+-

SUBSTITUTE SHEET (RULE 26)

TABLE 8

(H)-CTRAQFLKGC-(NH$_2$)

(H)-CHINQLRSIC-(NH$_2$)

(H)-CNRSQLLAAC-(NH$_2$)

(H)-CTSTQWLLAC-(NH$_2$)

(H)-CQRADLINFC-(NH$_2$)

(H)-CTLSEFLAGQQC-(NH$_2$)

(H)-CTFQVWKLARNC-(NH$_2$)

(H)-CTLGQWLQMGKC-(NH$_2$)

(H)-CLTGEFVTQWLYEC-(NH$_2$)

(H)-CTLREFLDPTTAVC-(NH$_2$)

(H)-CGTEGPTLSTWLDC-(NH$_2$)

(H)-CTLVGPSLMSWLTC-(NH$_2$)

(H)-CSLKEFLESGLMQC-(NH$_2$)

(H)-CTLAEFLASGVEQC-(NH$_2$)

(H)-CTLKEWLVSHEVWC-(NH$_2$)

(H)-CTEGPTLRQWLAARAC-(NH$_2$)

(H)-FEGPTLRQWM-(NH$_2$)

(H)-FEGPTLRQWLMSRS-(NH$_2$)

TABLE 9

	EC50 (nM) Micropnys.	EC50 (nM) Prolif.	IC50 (nM)
(H)-IEGPTLRQWLAARA-(NH2)	N.D.	++	++
(H)-CIEGPTLRQWLAARAC-(NH2)	N.D.	++	++
(H)-IEGPTLRQWLAARA | (H)-IEGPTLRQWLAARA(β-Ala)K-(NH2)	++	++	++
(H)-CIEGPTLRQWLAARA-(NH2) | (H)-CIEGPTLRQWLAARA-(NH2)	++	++	++

TABLE 10

(H)-IEGPTLRQWLAARA
|
(H)-IEGPTLRQWLAARA(β-Ala)K-(NH2)

	Sequence	EC50 (nM) Cell Prolif.	IC50 (nM)
	(Ac)-IEGPTLRQWLAARA | (Ac)-IEGPTLRQWLAARA-βA-K(NH2)	++	ND
	(H)-IEGPTLRQWLAAR | (H)-IEGPTLRQWLAAR-βA-K(NH2)	++	ND
	(H)-IEGPTLRQWLAA | (H)-IEGPTLRQWLAA-βA-K(NH2)	++(++)	ND
	(Ac)-EGPTLRQWLAARA | (Ac)-EGPTLRQWLAARA-βA-K(NH2)	ND	ND
	(H)-EGPTLRQWLAARA | (H)-EGPTLRQWLAARA-βA-K(NH2)	++	ND
	(H)-EGPTLRQWLAAR | (H)-EGPTLRQWLAAR-βA-K(NH2)	++(++)	ND
	(Ac)-EGPTLRQWLAA | (Ac)-EGPTLRQWLAA-βA-K(NH2)	++	ND
	(H)-EGPTLRQWLAA | (H)-EGPTLRQWLAA-βA-K(NH2)	++	ND

EXAMPLE 10

In this example various substitutions were introduced at positions G, P, and W in the cyclized compound

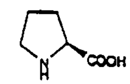
(H) - C A D G P T L R E W I S F C - (NH$_2$).

Table 11 lists examples of the substituted compounds that show TPO agonist activity. The substitutions abbreviated in the table are as follows:

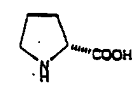
TABLE 11

(H) - C A D G P T L R E W I S F C - (NH$_2$)		
G	P	W
Sar	Hyp(OBn)	Nal
Sar	Hyp(OBn)	Nal
Gly	Pro	Trp
Gly	Pro	Trp
Sar	Hyp(OBn)	Nal
Gaba	Pro	Trp
Cpr-Gly	Pro	Trp
Sar	Hyp(OBn)	Nal
Gly	Pro	Trp
Gly	Pro	Nal
Sar	Pro	Trp
Cpr-Gly	L-Tic	Nal
Gly	D-Tic	D-Trp
Cpr-Gly	D-Tic	Trp
Gaba	Hyp(OBn)	Trp

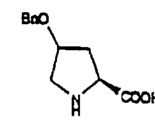
Proline Replacements



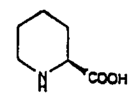
L-Pro



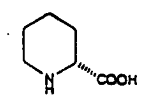
D-Pro



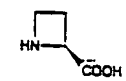
L-4-Hyp (OBn)



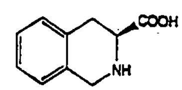
L-Pipecolinic acid



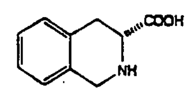
D-Pipecolinic acid



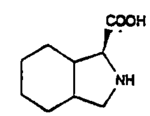
L-Azetidine carboxylic acid



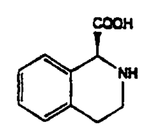
L-Tic



D-Tic

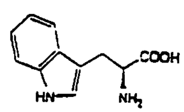


L-Oic

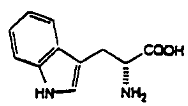


L-Tiq

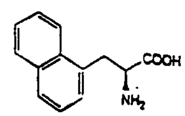
Tryptophan Replacements



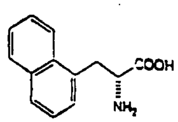
L-Trp



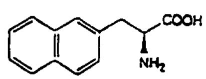
D-Trp



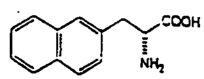
L-1-Nal



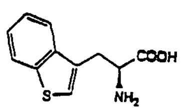
D-1-Nal



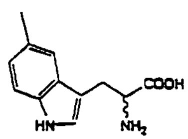
L-2-Nal



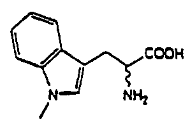
D-2-Nal



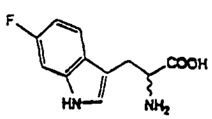
L-(Benzothienyl)-alanine



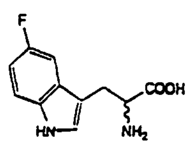
DL-5-Me-Trp



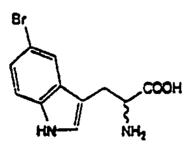
DL-1-Me-Trp



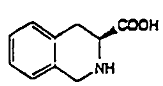
DL-6-F-Trp



DL-5-F-Trp



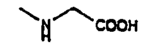
DL-5-Br-Trp



L-Tic

Glycine Replacements

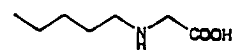
Glycine



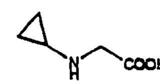
Sarcosine

β-alanine

γ-Aminobutyric acid



N-Pentyl glycine



N-Cyclopropyl glycine

EXAMPLE 11

To assess the feasibility of mice as a convenient test species, several *in vitro* experiments, designed to measure the activity of the test compounds on the mouse receptor, have been done. First, marrow cells, harvested from the femurs of 8 to 9 week one Balb/C mice, were incubated for 7 days in liquid culture with either rhuTPO or various concentrations of the test peptides. At the end of the incubation period, the cultures were concentrated by Cytospin, stained for acetylcholinesterase (AChE, a diagnostic of mouse megakaryocytes), and counted by microscopic analysis. One (1) nM rhuTPO gave rise to the outgrowth of very large (>40 um) non-adherent cells that stain for AChE. These cells appear to be mature megakaryocytes. From an initial seeding of 10^6 total marrow cells/ml (in 50 ml cultures) an estimated 1 to 2 x 10^6 megakaryocytes developed. This responce to TPO was designated as "maximal". Control cultures containing no added growth factors produced very few AChE-positive cells. Several of the peptide compounds were tested at high concentration in this assay and the results are summarized in Table 12. Peptide A at 10uM produced a maximal response of the mouse marrow. This finding was the first evidence that this peptide family is active on the murine receptor. In a second experiment, marrow cells were harvested and cultured in semi-solid medium (methylcellulose) containing either no factors, 1 nM rhuTPO, or 10uM Peptide A. After 7 days in culture, colonies of large cell (presumed to be megakaryocytes) were counted and grouped into small colonies (3-5 cells) or large colonies (greater than 6 cells). The results are shown in Table 13. TPO and the test peptides both produced substantially more colonies of both sized than did the negative control cultures. This indicates that the peptides mimic TPO in their ability to stimulate the expansion of the Mk precursor cell population.

To obtain a more quantitative comparison of the activity of the test compounds on murine and human receptors,

the muTPO receptor was cloned and transfected into BaF3 cells. A TPO dependent population of cells was isolated.

TABLE 12

Peptide	Concentration Tested (nM)	Response
D	100,000	none
C	40,000	maximal**
C + S.A.*	1000	maximal**
S.A. alone	1000	none
B	100,000	minimul
A	10,000	maximal**
TPO (R & D)	1	"maximal"

* Streptavidin complexed to biotinylated peptide - concentration of putative 1:4 complex.

** Compared to recombinant human TPO

** 25-30% ACE staining cells on cytopspin

No factor cultures - ca. 5% AChE staining cells (lower cellularity)

TABLE 13

Compound		3-5 large cells	6-12 large cells
No factors	1	2	1
No factors	2	1	1
1 nM TPO	#1-1	15	6
1 nM TPO	#1-2	12	1
1 nM TPO	#2-1	16	8
1 nM TPO	#2-2	13	3
10 uM Peptide	#1-1	25	10
10 uM Peptide	#1-2	22	8
10 uM Peptide	#2-1	22	7
10 uM Peptide	#2-2	21	10

The disclosures in this application of all articles and references, including patent documents, are incorporated herein by reference in their entirety for all purposes.

IN THE CLAIMS:

1. A compound that binds to thrombopoietin receptor, said compound having:

(1) a molecular weight of less than about 8000 daltons, and

(2) a binding affinity to thrombopoietin receptor as expressed by an IC_{50} of no more than about 100 μm.

2. The compound of Claim 1, wherein said compound is a peptide, and,

wherein from zero to all of the -C(O)NH- linkages of the peptide have been replaced by a linkage selected from the group consisting of a $-CH_2OC(O)NR-$ linkage; a phosphonate linkage; a $-CH_2S(O)_2NR-$ linkage; a $-CH_2NR-$ linkage; and a $-C(O)NR^6-$ linkage; and a -NHC(O)NH- linkage where R is hydrogen or lower alkyl and R^6 is lower alkyl,

further wherein the N-terminus of said peptide or peptide mimetic is selected from the group consisting of a $-NRR^1$ group; a -NRC(O)R group; a -NRC(O)OR group; a $-NRS(O)_2R$ group; a -NHC(O)NHR group; a succinimide group; a benzyloxycarbonyl-NH- group; and a benzyloxycarbonyl-NH- group having from 1 to 3 substituents on the phenyl ring selected from the group consisting of lower alkyl, lower alkoxy, chloro, and bromo, where R and R^1 are independently selected from the group consisting of hydrogen and lower alkyl,

and still further wherein the C-terminus of said peptide or peptide mimetic has the formula $-C(O)R^2$ where R^2 is selected from the group consisting of hydroxy, lower alkoxy, and $-NR^3R^4$ where R^3 and R^4 are independently selected from the group consisting of hydrogen and lower alkyl and where the nitrogen atom of the $-NR^3R^4$ group can optionally be the amine group of the N-terminus of the peptide so as to form a cyclic peptide,

and physiologically acceptable salts thereof.

3. A pharmaceutical composition comprising the compound of Claim 1 in combination with a pharmaceutically acceptable carrier.

4. A method for treating a patient suffering from a disorder that is susceptible to treatment with a thrombopoietin agonist, comprising admistering to the patient, a therapeutically effective dose or amount of a compound of Claim 1.

5. The method of Claim 4, wherein the compound administered to the patient is a peptide, and,

wherein from zero to all of the -C(O)NH- linkages of the peptide have been replaced by a linkage selected from the group consisting of a $-CH_2OC(O)NR-$ linkage; a phosphonate linkage; a $-CH_2S(O)_2NR-$ linkage; a $-CH_2NR-$ linkage; and a $-C(O)NR^6-$ linkage; and a -NHC(O)NH- linkage where R is hydrogen or lower alkyl and R^6 is lower alkyl,

further wherein the N-terminus of said peptide or peptide mimetic is selected from the group consisting of a $-NRR^1$ group; a -NRC(O)R group; a -NRC(O)OR group; a $-NRS(O)_2R$ group; a -NHC(O)NHR group; a succinimide group; a benzyloxycarbonyl-NH- group; and a benzyloxycarbonyl-NH- group having from 1 to 3 substituents on the phenyl ring selected from the group consisting of lower alkyl, lower alkoxy, chloro, and bromo, where R and R^1 are independently selected from the group consisting of hydrogen and lower alkyl,

and still further wherein the C-terminus of said peptide or peptide mimetic has the formula $-C(O)R^2$ where R^2 is selected from the group consisting of hydroxy, lower alkoxy, and $-NR^3R^4$ where R^3 and R^4 are independently selected from the group consisting of hydrogen and lower alkyl and where the nitrogen atom of the $-NR^3R^4$ group can optionally be the amine group of the N-terminus of the peptide so as to form a cyclic peptide,

and physiologically acceptable salts thereof.

6. The compound of Claim 2, wherein said compound comprises a sequence of amino acids:

$$X_1\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7$$

where X_1 is C, L, M, P, Q, V; X_2 is F, K, L, N, Q, R, S, T or V; X_3 is C, F, I, L, M, R, S, V or W; X_4 is any of the 20 genetically coded L-amino acids; X_5 is A, D, E, G, K, M, Q, R, S, T, V or Y; X_6 is C, F, G, L, M, S, V, W or Y; and X_7 is C, G, I, K, L, M, N, R or V.

7. The compound of claim 6, wherein said sequence of amino acids is cyclized.

8. The compound of claim 6, wherein said sequence of amino acids is dimerized.

9. The compound of Claim 6, wherein the compound comprises the sequence of amino acids

$$C\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7$$

where X_2 is K, L, N, Q, R, S, T or V; X_3 is C, F, I, L, M, R, S or V; X_4 is any of the 20 genetically coded L-amino acids; X_5 is A, D, E, G, S, V or Y; X_6 is C, F, G, L, M, S, V, W or Y; and X_7 is C, G, I, K, L, M, N, R or V.

10. The compound of Claim 8, wherein X_4 is A, E, G, H, K, L, M, P, Q, R, S, T, or W.

11. The compound of Claim 10, wherein X_2 is S or T; X_3 is L or R; X_6 is R; X_5 is D, E, or G; X_6 is F, L, or W; and X_7 is I, K, L, R, or V.

12. The compound of Claim 9, wherein said compound comprises a sequence of amino acids:

$$X_8\ C\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7$$

where X_2 is F, K, L, N, Q, R, S, T or V; X_3 is C, F, I, L, M, R, S, V or W; X_4 is any of the 20 genetically coded L-amino acids; X_5 is A, D, E, G, K, M, Q, R, S, T, V or Y; X_6 is C, F, G, L, M, S, V, W or Y; X_7 is C, G, I, K, L, M, N, R or V; and X_8 is any of the 20 genetically coded L-amino acids.

13. The compound of Claim 12, wherein X_8 is G, S, Y or R.

14. The compound of Claim 12, wherein said compound comprises a sequence of amino acids: G G C T L R E W L H G G F C G G.

15. The compound of Claim 6, wherein said compound comprises a sequence of amino acids:

$$X_8\ G\ X_1\ X_2\ X_3\ X_4\ X_5\ W\ X_7$$

where X_1 is L, M, P, Q, or V; X_2 is F, R, S, or T; X_3 is F, L, V, or W; X_4 is A, K, L, M, R, S, V, or T; X_5 is A, E, G, K, M, Q, R, S, or T; X_7 is C, I, K, L, M or V; and X_8 is any of the 20 genetically coded L-amino acids.

16. The compound of Claim 15, wherein X_1 is P; X_2 is T; X_3 is L; X_4 is R; X_5 is E or Q; X_7 is I or L.

17. The compound of Claim 16, wherein said compound comprises a sequence of amino acids:

$$X_9\ X_8\ G\ X_1\ X_2\ X_3\ X_4\ X_5\ W\ X_7$$

where X_8 is A, C, D, E, K, L, Q, R, S, T, or V; and X_9 is A, C, E, G, I, L , M, P, R, Q, S, T, or V.

18. The compound of Claim 17, wherein X_8 is D, E, or K; and X_9 is A or I.

19. The compound of Claim 18, wherein said compound is selected from the group consisting of G G C A D G P T L R E W I S F C G G; G N A D G P T L R Q W L E G R R P K N; G G C A D G P T L R E W I S F C G G K; T I K G P T L R Q W L K S R E H T S; S I E G P T L R E W L T S R T P H S; L A I E G P T L R Q W L H G N G R D T; C A D G P T L R E W I S F C; and I E G P T L R Q W L A A R A.

20. The method of Claim 4, wherein said compound that is administered to the patient comprises a sequence of amino acids:

$$C\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7$$

where X_2 is K, L, N, Q, R, S, T or V; X_3 is C, F, I, L, M, R, S or V; X_4 is any of the 20 genetically coded L-amino acids; X_5 is A, D, E, G, S, V or Y; X_6 is C, F, G, L, M, S, V, W or Y; and X_7 is C, G, I, K, L, M, N, R or V.

21. The method of Claim 20, wherein X_4 is A, E, G, H, K, L, M, P, Q, R, S, T or W.

22. The method of Claim 21, wherein X_2 is S or T; X_3 is L or R; X_4 is R; X_5 is D, E, or G; X_6 is F, L, or W; and X_7 is I, K, L, R, or V.

23. The method of Claim 22, wherein said compound that is administered to the patient comprises a sequence of amino acids: G G C T L R E W L H G G F C G G.

24. The method of Claim 4, wherein the disorder susceptible to treatment with a thrombopoietin agonist is selected from the group consisting of:
hematological disorders and thrombocytopenia resulting from chemotherapy, radiation therapy, or bone marrow transfusions.

25. The method of Claim 4, wherein said compound that is administered to the patient comprises a sequence of amino acids:

$$X_8\ G\ X_1\ X_2\ X_3\ X_4\ X_5\ W\ X_7$$

where X_1 is L, M, P, Q, or V; X_2 is F, R, S, or T; X_3 is F, L, V, or W; X_4 is A, K, L, M, R, S, V, or T; X_5 is A, E, G, K, M, Q, R, S, or T; X_7 is C, I, K, L, M or V; and X_8 residue is any of the 20 genetically coded L-amino acids.

26. The method of Claim 25, wherein X_1 is P; X_2 is T; X_3 is L; X_4 is R; X_5 is E or Q; X_7 is I or L.

27. The method of Claim 26, wherein said compound comprises a sequence of amino acids:

$$X_9\ X_8\ G\ X_1\ X_2\ X_3\ X_4\ X_5\ W\ X_7$$

where X_8 is A, C, D, E, K, L, Q, R, S, T, or V; and X_9 is A, C, E, G, I, L , M, P, R, Q, S, T, or V.

28. The method of Claim 27, wherein X_8 is D, E, or K; and X_9 is A or I.

29. The method of Claim 28, wherein the compound that is administered to the patient is selected from the group consisting of G G C A D G P T L R E W I S F C G G; G N A D G P T L R Q W L E G R R P K N; G G C A D G P T L R E W I S F C G G K; T I K G P T L R Q W L K S R E H T S; S I E G P T L R E W L T S R T P H S; L A I E G P T L R Q W L H G N G R D T; C A D G P T L R E W I S F C; and I E G P T L R Q W L A A R A.

30. A compound that binds to thrombopoietin receptor, wherein said compound is selected from the group consisting of

C A D G P T L R E W I S F C ;

[Ac] - C A D G P T L R E W I S F C - [amide] ;

O = C A D G P T L R E W I S F C - NH_2 ; and
CH_2 ——— S

I E G P T L R Q W L A A R A
I E G P T L R Q W L A A R A (βala) - K [NH_2]

31. A method for treating a patient suffering from a disorder that is susceptible to treatment with a thrombopoietin agonist, comrpising administering to the pateint a compound is selected from the group consisting of

C A D G P T L R E W I S F C ;

[Ac] - C A D G P T L R E W I S F C - [amide] ;

O = C A D G P T L R E W I S F C - NH_2 ; and
CH_2 ——— S

I E G P T L R Q W L A A R A
I E G P T L R Q W L A A R A (βala) - K [NH_2]

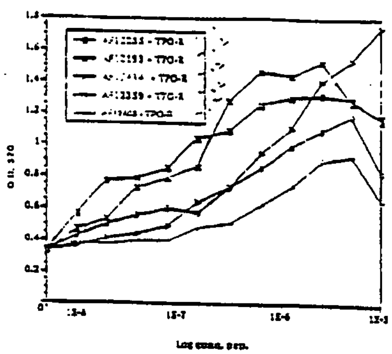


FIG. 1A

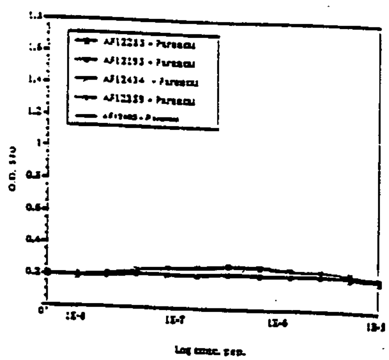


FIG. 1B

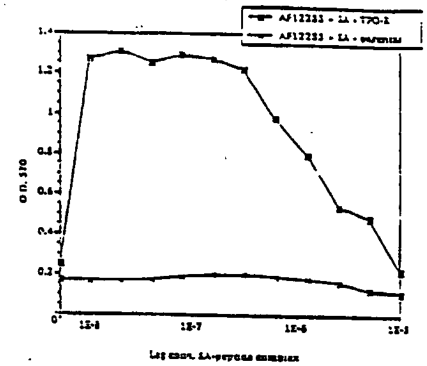


FIG. 2A

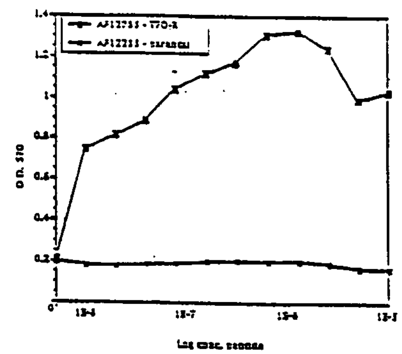


FIG. 2B

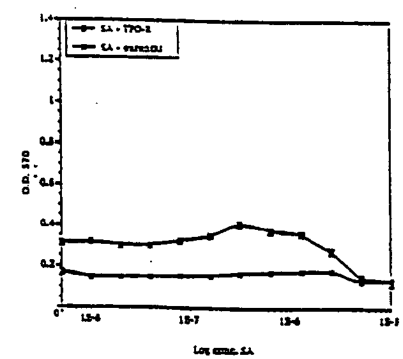


FIG. 2C

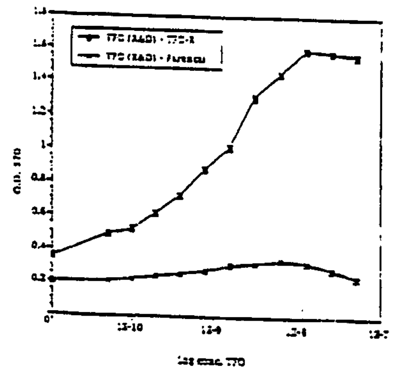


FIG. 3A

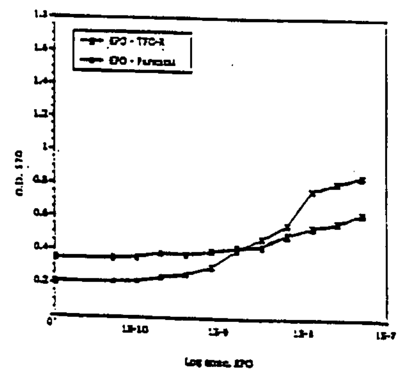


FIG. 3B

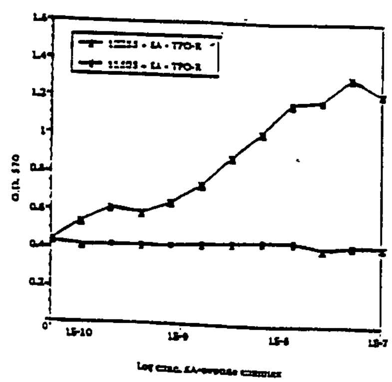


FIG. 3C

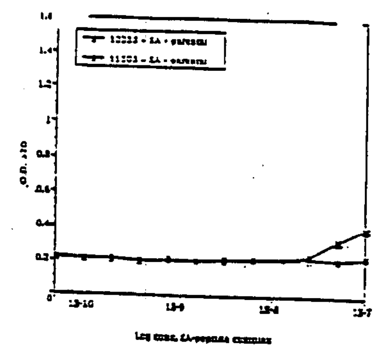


FIG. 3D

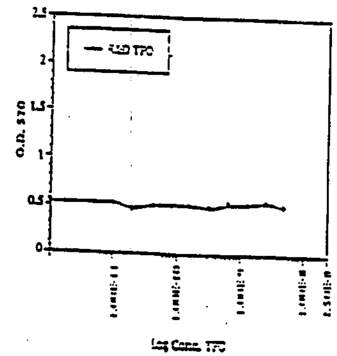


FIG. 3E

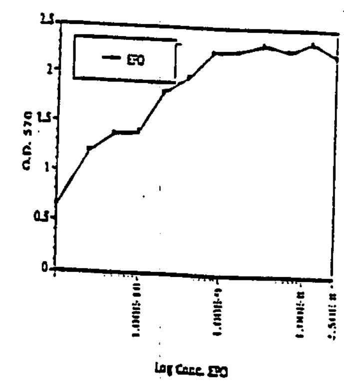


FIG. 3F

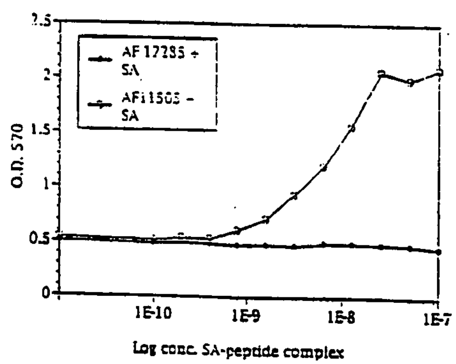


FIG. 3G

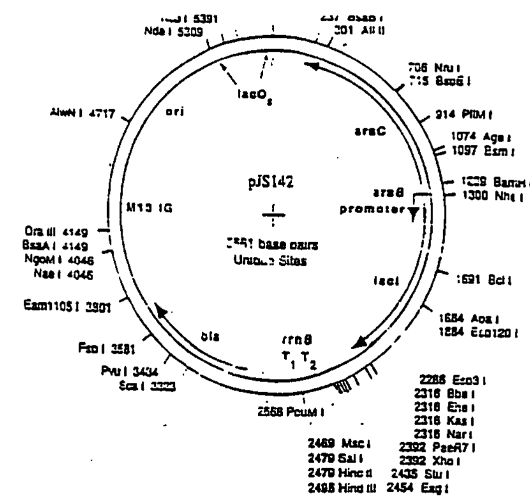
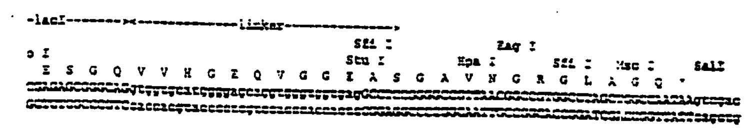


FIG. 4A

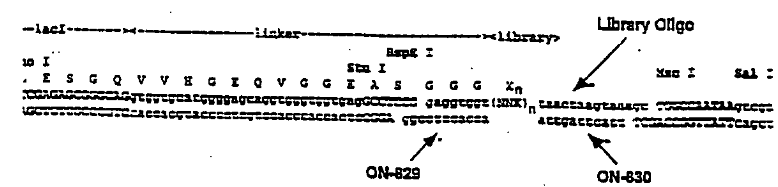
pJS142 Library Vector, cloning sites at 3' end of laci gene:

FIG. 4B



library Construction after SfiI digestion:

FIG. 4C



(a) pELM3/pELM15 MBP vector cloning sites: Fig. 5A

```
---MBP----> <-------------------------linker------------------------> <----Xa
              Sac I
Q   T   N   S   S   S   N   N   N   N   N   N   N   N   N   N   L   G   I   E
CAG ACT AAT TCG AGC TCG AAC AAC AAC AAC AAT AAC AAT AAC AAC AAC CTC GGG ATC GAG
GTC TGA TTA AGC TCG AGC TTG TTG TTG TTG TTA TTG TTA TTG TTG TTG GAG CCC TAG CTC
```

```
Xa----> <-------------------------------cloning sites--------------------------->
        Age I   Pml I     Sma I   EcoR I  BamH I  Xba I    Sal I   Pst I     Hind III
G   R   T   G   H   V   A   R   E   F   G   S   S   R   V   D   L   Q   A   S
GGA AGG ACC GGT CAC GTG GCC CGG GAA TTC GGA TCC TCT AGA GTC GAC CTG CAG GCA AGC TT
CCT TCC TGG CCA GTG CAC CGG GCC CTT AAG CCT AGG AGA TCT CAG CTG GAC GTC CGT TCG AA
```

(b) pELM3/pELM15 after subcloning of library insert: Fig. 5B

```
Xa----> <----linker---> <library>
                                       Msc I         Sal I
G   R   T   G   G   G   Xn     *
GGA AGG ACC GGA GGT GGT (NNK)n TAA CTA AGT AAA GCT GGC CAA TAA GTC GAC
CCT TCC TGG CCT CCA CCA (NNM)n ATT GAT TCA TTT CGA CCG GTT ATT CAG CTG
```

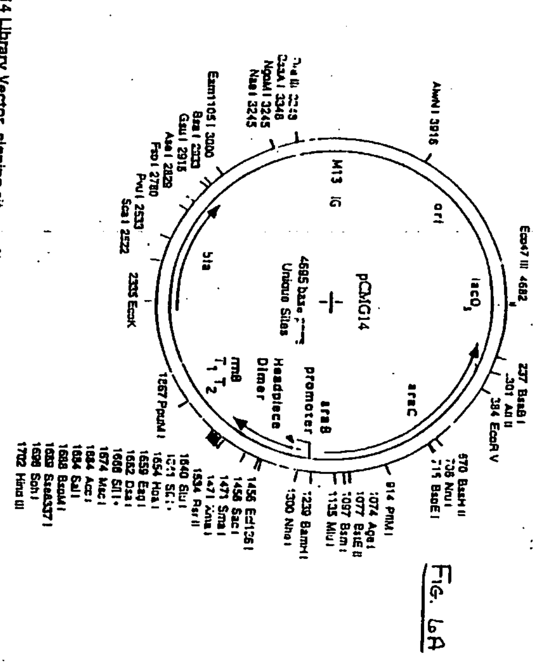



Fig. 6A

pCMG14 Library Vector, cloning sites at 3' end of Headpiece Dimer gene:

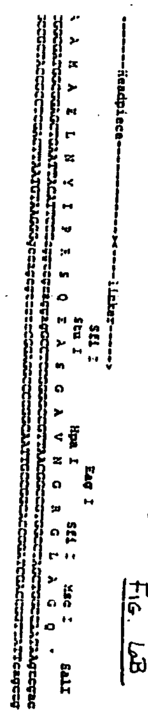


Fig. 6B

Library Construction after SfiI digestion:

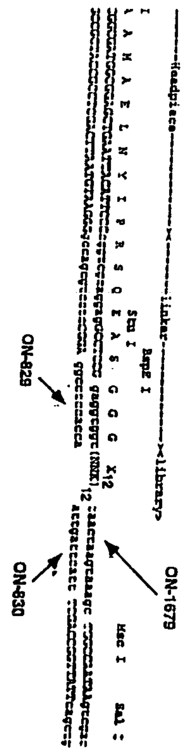
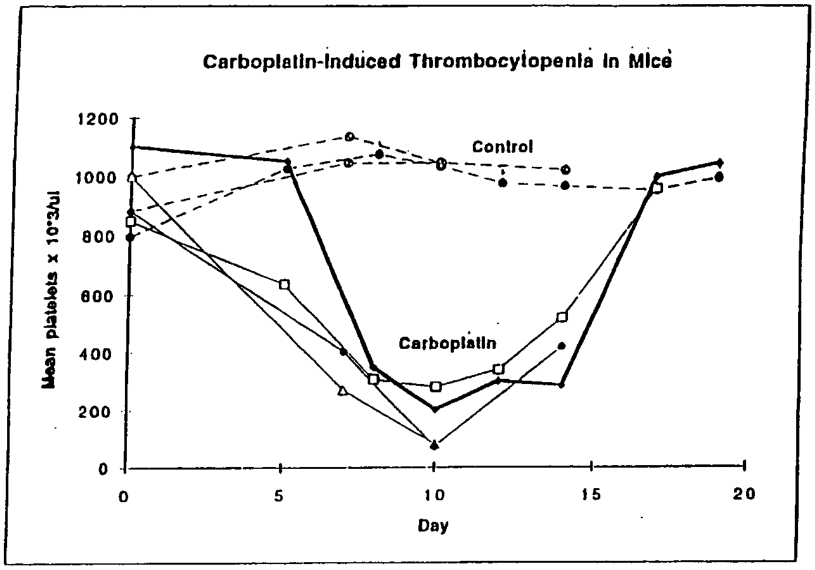


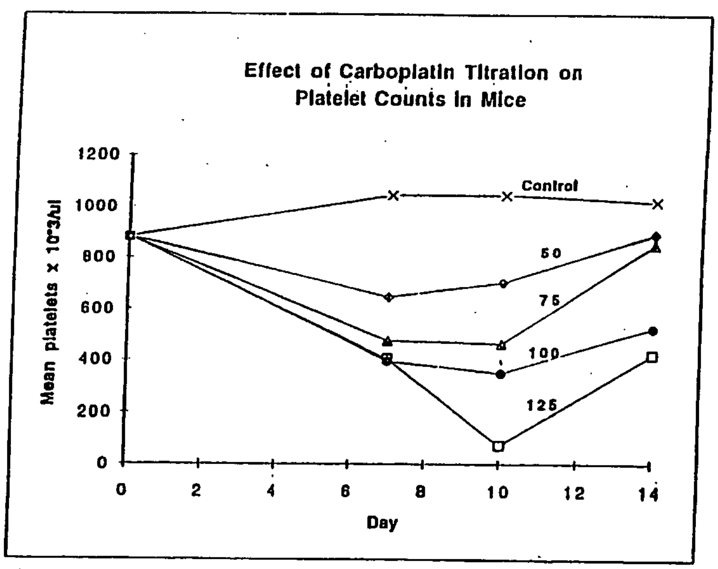
Fig. 6C



BALB/c mice received carboplatin (125 mg/kg, ip) on Day 0.
Dashed lines represent controls from three experiments.
Solid lines represent carboplatin-treated groups in three experiments.
The heavy solid lines represent historical data from Ulich, et al.

3/96 Chris Boytos

FIG. 7

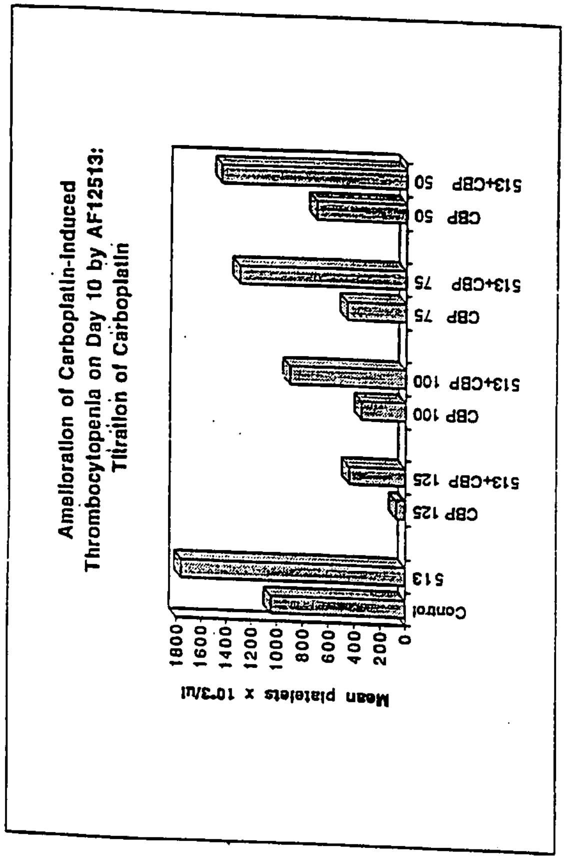


Carboplatin (mg/kg, ip) was given on Day 0.

3/96 Chris Boytos

FIG. 8

Fig. 9



Carboplatin (CBP; 125-50 mg/kg, ip) was given on Day 0.
AF12513 (513; 1000 mg/kg, ip) was given on Days 1-9.

3/96 Chris Boylos

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/09623

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :C07K 7/02, 7/06, 7/08, 7/50, 7/54, 14/52
US CL : 514/09, 11, 13, 14, 15, 16; 530/317, 323, 326, 327, 328, 329
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 514/09, 11, 13, 14, 15, 16; 530/317, 323, 326, 327, 328, 329

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, DIALOG, MEDLINE
search terms: thrombopoietin, ligand, fragment, agonist, antagonist, receptor, mimetic, inhibit

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,358,934 A (BOROVSKY ET AL) 25 October 1994 (25.10.94), see column 2, line 64-column 3, line 8.	1-31
A	US 5,141,851 A (BROWN ET AL.) 25 August 1992 (25.08.92), see column 9, lines 40-52.	1-31
A	US 5,411,942 A (WIDMER ET AL.) 02 May 1995 (02.05.95), see column 5, line 37-column 6, line 11.	1-31
A, P	WO 96/17062 A1 (ZYMOGENETICS,INC.) 06 June 1996 (06.06.96), see entire document.	1-31

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 AUGUST 1996	17 SEP 1996
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer GREGORY RITCHIE Telephone No. (703) 308-0196

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/09623

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KATO et al. Purification and Characterization of Thrombopoietin. J. Biochem. 1995, Vol. 118, pages 229-236, see entire document.	1-31
A, P	WADA et al. Characterization of the Truncated Thrombopoietin Variants. Biochemical and Biophysical Research Communications. 24 August 1995, Vol. 213, No. 3, pages 1091-1098, see entire document.	1-31

European Patent Register Extract

EUROPEAN PATENT REGISTER / EPIDOS 24/09/2002

AN: 96919241.8 PN: 0885242 IPC: C07K7/02

PART I - REGISTER OF EUROPEAN PATENTS (R92 EPC)

PUBLICATION NUMBER	: 0885242
APPLICATION NUMBER	: 96919241.8
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SUPPLEMENTARY SEARCH REPORT	: 04.02.2000
INTERNATIONAL APPLICATION NR.	: US9609623
INTERNAT. PUBL. NUMBER AND DATE	: WO96040750 19.12.1996
FILING DATE	: 07.06.1996
PRIORITY	: 07.06.1995/ US 485301 07.06.1995/ US 478128
CLASSIFICATION	: C07K7/02, C07K7/06, C07K7/08, C07K7/50, C07K7/54, C07K14/52
DESIGNATION	: AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
TITLE	: PEPTIDES AND COMPOUNDS THAT BIND TO A THROMBOPOIETIN RECEPTOR
APPLICANT	: FOR : ALL DESIGNATED STATES GLAXO GROUP LIMITED GLAXO WELLCOME HOUSE, BERKELEY AVENUE GREENFORD, MIDDLESEX UB6 0NN/GB
INVENTOR	: DOWER, WILLIAM, J./2307 BRANNER AVENUE/ MENLO PARK, CA 94025/US BARRET, RONALD, W./12900 ARROYO DE ARQUELLO/SARATOGA, CA 95070/US CWIRLA, STEVEN, E./111 HEDGE ROAD/MENLO PARK, CA 94025/US DUFFIN, DAVID, J./1735 WOODLAND AVENUE 13/EAST POLO ALTO, CA 94303/US GATES, CHRISTIAN, M./5770 A CROY ROAD/ MORGAN HILL, CA 95037/US HASELDEN, SHERRIL, S./27 EASTRIDGE DRIVE/SANTA CRUZ, CA 95060/US MATTHEAKIS, LARRY, C./20612 SUNRISE DRIVE/CUPERTINO, CA 95014/US SCHATZ, PETER, J./2080 MARICH WAY 15/ MOUNTAIN VIEW, CA 94040/US WAGSTROM, CHRISTOPHER, R./1909 FARNDON AVENUE/LOS ALTOS, CA 94024/US WRIGHTON, NICHOLAS, C./2030 AMHERST STREET/PALO ALTO, CA 94304/US
REPRESENTATIVE	: FILLER, WENDY ANNE, DR., ET AL GLAXOSMITHKLINE CORPORATE INTELLECTUAL PROPERTY (CN9.25.1) 980 GREAT WEST ROAD BRENTFORD, MIDDLESEX TW8 9GS/GB
REQUEST FOR EXAMINATION	: 22.12.1997

PART II - INFORMATION REGISTER (EPIDOS)

THIS APPLICATION IS BEING TREATED IN (/FAX-NR): MUNICH /(+49-89) 23994465
THE PROCEDURE LANGUAGE IS (DE/EN/FR) : EN
PCT - CHAPTER II
REQUEST FOR PRELIMINARY EXAMINATION FILED: 04.10.1996
ACTS PERFORMED FOR ENTRY INTO THE REGIONAL PHASE : 12.11.1997
- NATIONAL BASIC FEE PAID : 12.11.1997

European Patent Register Extract

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- SEARCH FEE PAID                                : 31.12.1997
- DESIGNATION FEE(S) PAID                        : 12.11.1997
- EXAMINATION FEE PAID                           : 22.12.1997
---------------------------------------------------------------------
CHAPTER - EXTENSION OF THE PATENT
---------------------------------------------------------------------
COUNTRY-CODE / DATE PAYMENT / DATE WITHDRAWAL : AL/12.11.1997/00.00.0000
COUNTRY-CODE / DATE PAYMENT / DATE WITHDRAWAL : LT/12.11.1997/00.00.0000
COUNTRY-CODE / DATE PAYMENT / DATE WITHDRAWAL : LV/12.11.1997/00.00.0000
COUNTRY-CODE / DATE PAYMENT / DATE WITHDRAWAL : SI/12.11.1997/00.00.0000
---------------------------------------------------------------------
CHAPTER - RENEWAL FEES (ART.86)
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RENEWAL FEE A.86 (PATENT YEAR/PAID)            : 03/15.06.1998
                                                 04/14.06.1999
                                                 05/13.06.2000
                                                 06/13.06.2001
                                                 07/12.06.2002
---------------------------------------------------------------------
CHAPTER - CITED DOCUMENTS
THIS CHAPTER SHOWS THE ACTUAL SITUATION OF THE CITED DOCUMENTS.
NO OBLIGATION IS TAKEN FOR THE COMPLETENESS OF ALL THE CASES.
---------------------------------------------------------------------
** CITED IN THE INTERNATIONAL SEARCH **
A  :US A  5 358 934
A  :US A  5 141 851
A  :US A  5 411 942
AP :WO A  9 617 062
** CITED IN THE EUROPEAN SEARCH **
A  :LU A     88 573
PA :WO A  9 521 919
** CITED IN THE INTERNATIONAL SEARCH **
A  :J. BIOCHEM., 1995, VOL. 118, KATO ET AL., "PURIFICATION AND
    CHARACTERIZATION OF THROMBOPOIETIN", PAGES 229-236.
AP :BIOCHEMICAL AND BIOPHYSICAL RESEARCH COMMUNICATIONS, 24 AUGUST 1995, VOL.
    213, NO. 3, WADA ET AL., "CHARACTERIZATION OF THE TRUNCATED THROMBOPOIETIN
    VARIANTS", PAGES 1091-1098.
** END OF DATA **
```